Report Rapport

Atomic Energy Control Board

Commission de contrôle de l'énergie atomique

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REPORT ON TESTS USING A FLOW VISUALIZATION RIG - THREE CHANNEL PER PASS CONFIGURATION

by

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Research report

REPORT ON TESTS USING A FLOW VISUALIZATION RIG - THREE CHANNEL PER PASS CONFIGURATION

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ABSTRACT

The flow visualization rig was upgraded to have 3 heated channels per pass. A series of natural circulation flow tests were done. Under test conditions, long periods of flow stagnation with high heater temperatures were observed in one of the channels. This 3 channel per pass rig shows flow patterns with some reverse channel flows, together with continued heat removal by the boiler.

RESUME

L'assemblage de visualisation du débit a été amélioré pour comporter trois canaux chauffés par passage. On a procédé à une série d'essais de débit par circulation naturelle. Dans des conditions d'essai, on a observé, dans un des canaux, de longues périodes de stagnation du débit où l'élément chauffant demeurait à de hautes températures. Le nouvel assemblage de trois canaux par passage montre des modèles de débit où le débit est refoulé dans certains canaux pendant que le générateur de vapeur continue d'évacuer la chaleur.

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1.0 INTRODUCTION

The basic design of the modified flow visualization rig, which is described in Volume 1 of this report, involved two heated channels per pass in the figure-of-eight configuration. This volume describes additional work that was done with a third channel per pass added to the rig.

Modifications of the earlier rig included:

1) Addition of one new heated channel in each pass.
2) Provision for changing the length of the headers.
3) Addition of a heated surge tank.
4) Provision of reduced diameter vertical sections for the inlet feeders.
5) The pyrex tubing used for the heated channels was replaced with LEXAN.

A series of tests was done with the new 3 channel per pass rig to provide design assistance for a high pressure rig, and to study behaviour of the figure-of-eight heat transport loop during natural circulation cooling. Some tests were done with one channel in each pass disconnected for comparison with the previous two-channel tests.

This report describes all the tests done on the rig after the new channels were added. The final configuration of the rig is shown in Figure 1.

2.0 CHANNEL 2 PRESSURE DROP MEASUREMENTS

With the rig cold, and the pumps running, the pressure drop between the inlet and outlet of channel 2 was measured for different flows. Flow was obtained by using a stopwatch to determine flow velocity. Particles

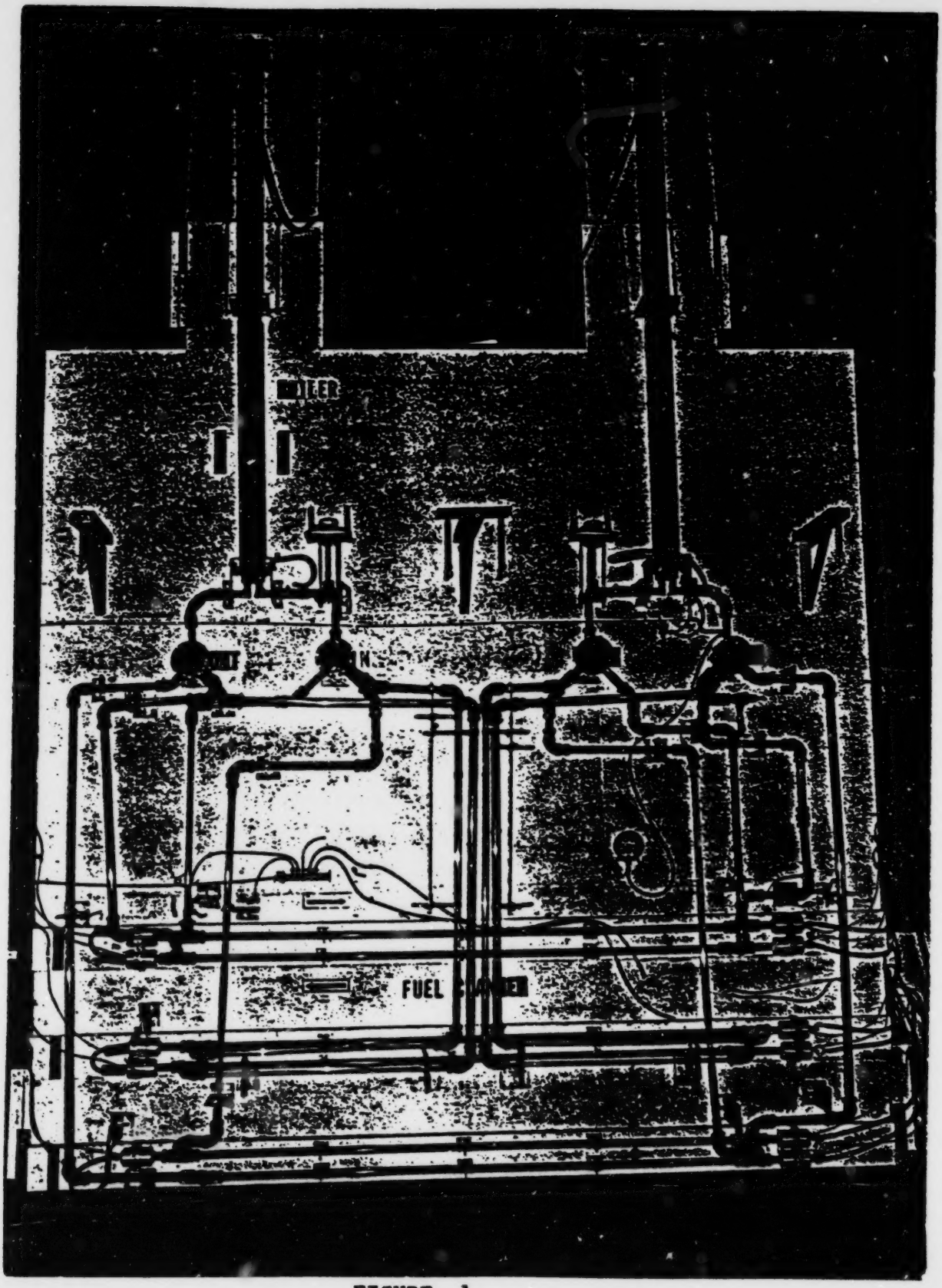

FIGURE 1

FINAL RIG CONFIGURATION

entrained in the water within the rig could be observed, and their velocity was determined by measuring the time interval required for the particles to traverse a straight section of feeder pipe. Feeder flow area and liquid density were used to translate the flow velocity to mass flow rate.

Figure 2.1 shows the observed channel 2 pressure drop as a function of flow. A least squares fit to the data gives:

$$\Delta P = .40 + 121.78\ w^2$$

where ΔP = pressure drop (kPa)
w = mass flow rate (kg/s)

The overall head loss factor for the channel can be derived from the data:

$$k + \frac{fl}{d} = 121.78 \times 2 \times \rho \times A^2 \times 1000$$

where k = form loss coefficient
f = friction factor
l = length
d = equivalent hydraulic diameter
A = flow area = 2.93×10^{-4} m²

Therefore, the overall head loss factor is

$$k + \frac{fl}{d} = 121.78 \times 2 \times (1000 \times 2.93 \times 10^{-4})^2$$
$$= 20.9$$

3.0 HEAT LOSS CALCULATIONS

A slow power ramp experiment was used to determine heat losses to atmosphere from primary piping in the flow visualization rig. The slow power ramp was used because of the long duration of the experiment. The rig was kept hot and allowed to reach thermal equilibrium after each power increment, thereby ensuring accurate heat loss determination.

FLOW VISUALIZATION RIG

CHANNEL 2 FLOW CHARACTERISTIC

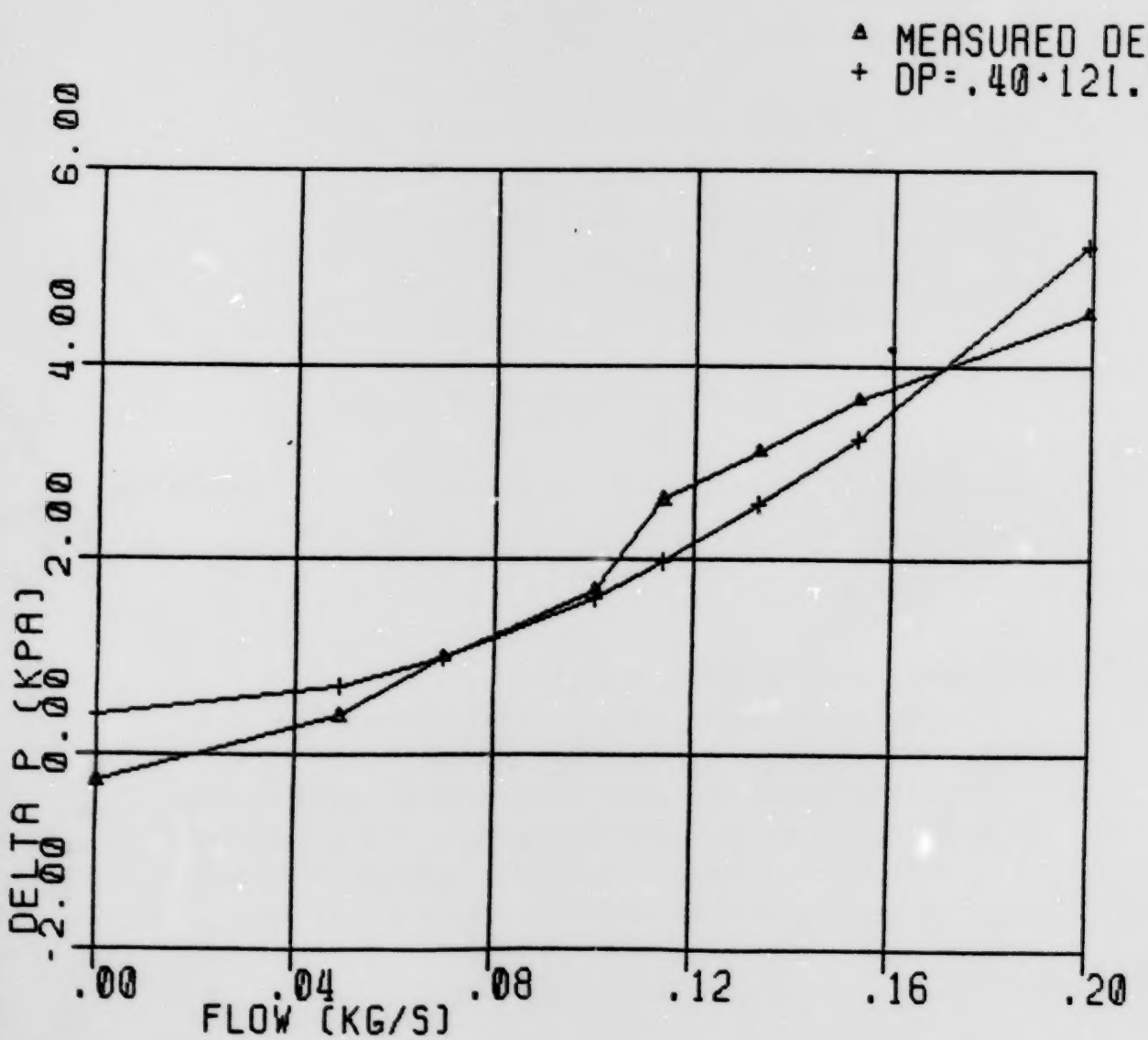

FIGURE 2.1

The experiment was started with the rig thermosyphoning at a low initial power level. Figure 3.1 shows the power for each pair of heated channels during the experiment. Thermosyphoning flow was established at 260s, and the experiment began at this time. At each power level, temperatures in the rig were allowed to stabilize before power was increased. The average temperature rise across the heated channels was calculated, and compared with the temperature drop across the boiler. The heat loss from the rig is given by:

$$\Delta H = \frac{\Delta T_{ch} - \Delta T_B}{\Delta T_{ch}} \quad x\ 100\%$$

where ΔH = heat loss (percent)

ΔT_{ch} = average channel temperature rise (°C)

ΔT_B = temperature drop across boiler (°C)

Figure 3.2 shows the calculated heat loss from the flow visualization rig as a function of rig temperature. If anomalies in the data are ignored, it could be said that the average calculated heat loss is about 50% for temperatures above 55°C.

For the slow power ramp test, a secondary feedwater flow of .03 kg/s was used. Some boiling occurred in the rig for powers above 8 kW, and the average rig temperature was about 75° when boiling occurred. Figure 3.2 indicates that about fifty percent of the power input to the rig is lost to the environment when the average coolant temperature is 75°C. It can be concluded that under single phase thermosyphoning conditions, with the secondary feedwater flow used here, maximum heat loss from the rig to the environment is fifty percent of the power input. All the tests done with the rig had feedwater flows between .02 kg/s and .04 kg/s, and therefore maximum heat losses to the environment during the tests were fifty percent of the power input.

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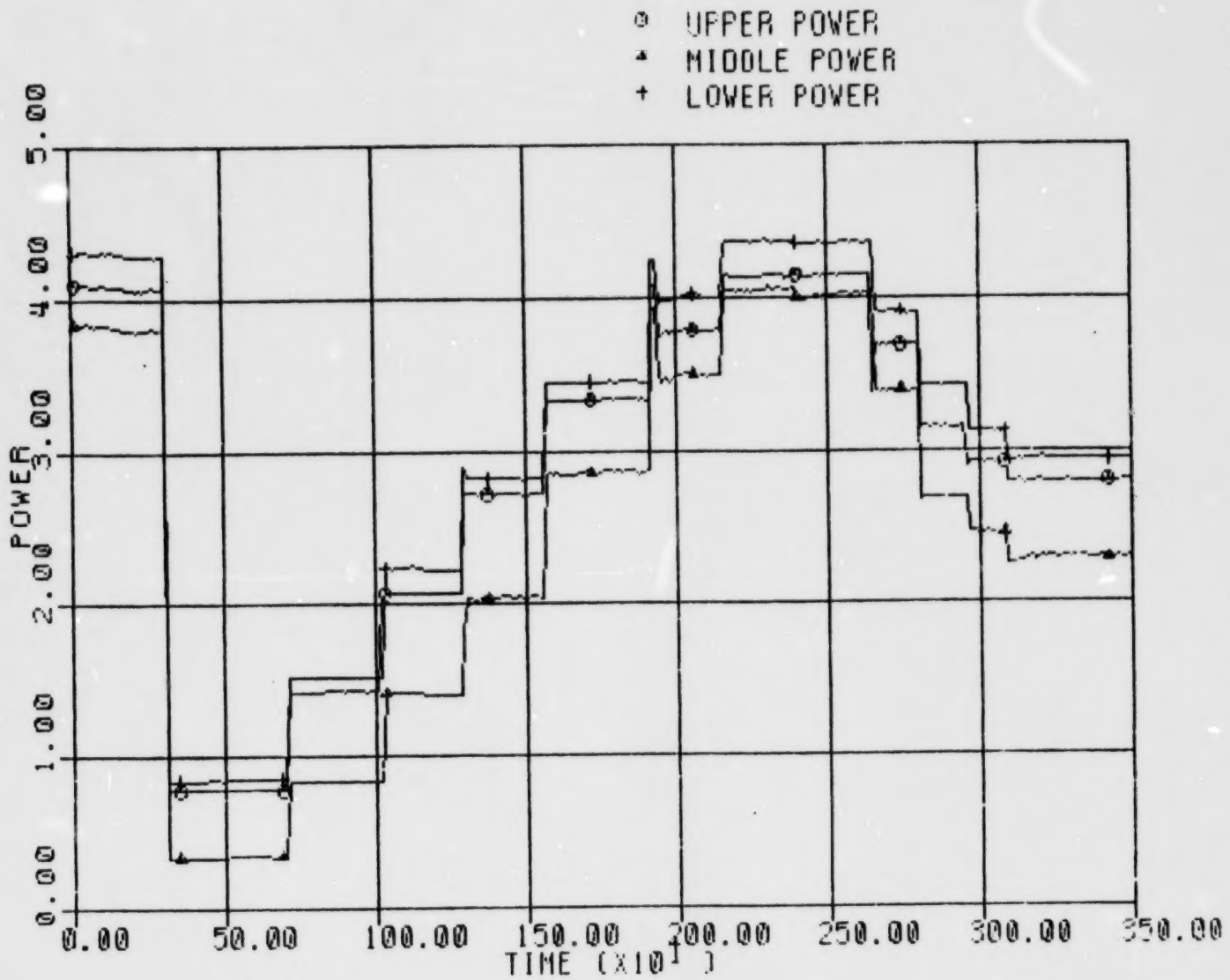

FIGURE 3.1

FLOW VISUALIZATION RIG

HEAT LOSS

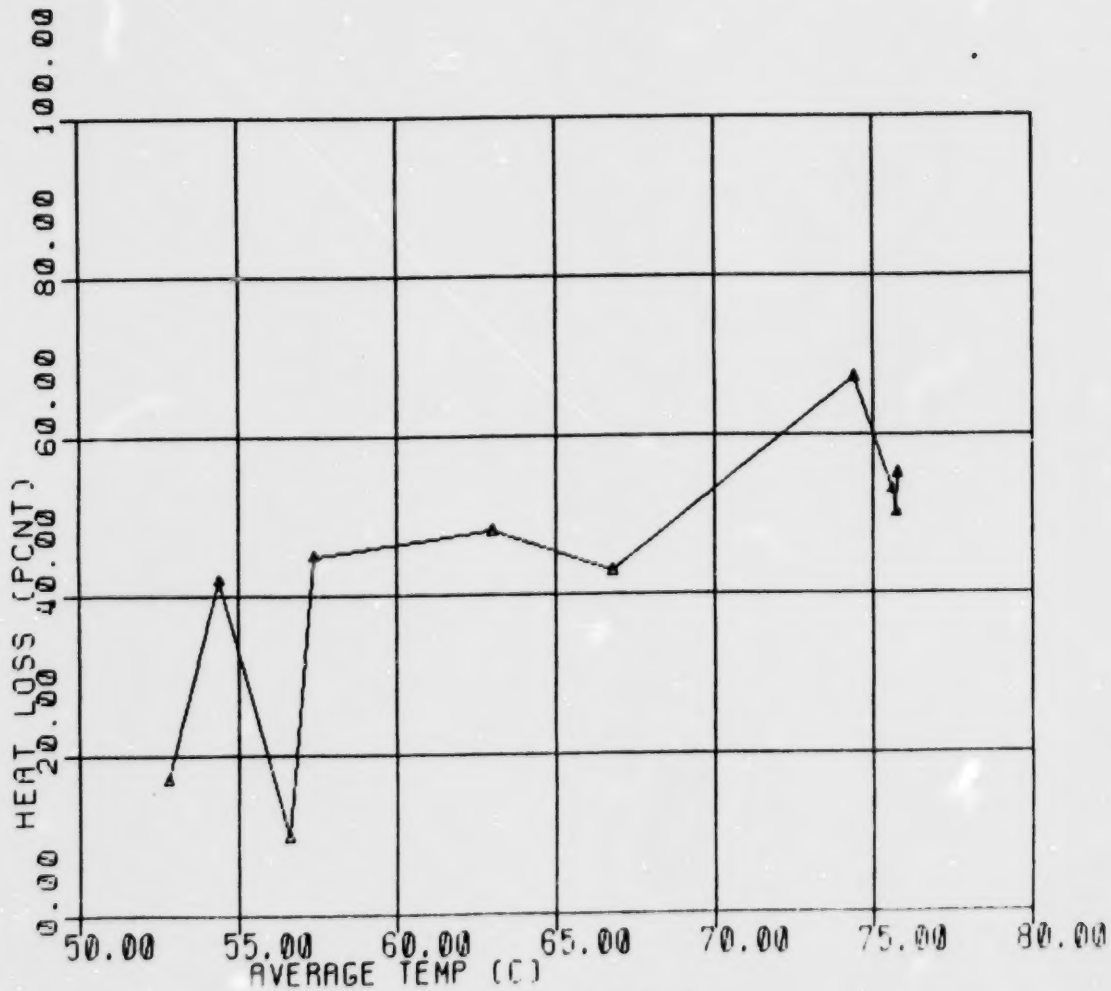

FIGURE 3.2

4.0 FLOW VISUALIZATION RIG TEST RESULTS

Appendix B provides a summary of all the tests carried out to date with the flow visualization rig. All data logged during the tests are stored on tape at Monserco, and can be accessed at any time for further analysis if required. The results of selected tests which showed significant characteristics of the flow visualization rig are presented here.

The flow visualization rig with three heated channels per pass was first used to provide experimental assistance to International Development and Energy Assessment Inc. (IDEA) for their work in designing a high pressure rig for studying thermosyphoning. The main area of interest to IDEA was the effect of header geometry on natural circulation flow patterns, and the inter-relationships affecting behaviour of the different channels in the rig.

4.1 Boiling Threshold Tests

These tests were done between August 23 and August 28, 1984. The objective of the tests was to determine the required distribution of power in the channels to cause boiling in any selected pair of channels. Starting from a single phase forward flow thermosyphoning condition , power was raised in a selected pair of channels to determine the threshold for boiling. Figure 4.1-1 and 4.1-2 show the power and channel temperatures for the top channel boiling threshold experiment. Channel 1 began to boil at about 7800 s, with total upper circuit power at 3.6 kW. Middle and lower circuit powers were at 2.1 kW and 2.3 kW respectively. This experiment was the first in the series and provided the power settings required to give boiling in the upper channels only.

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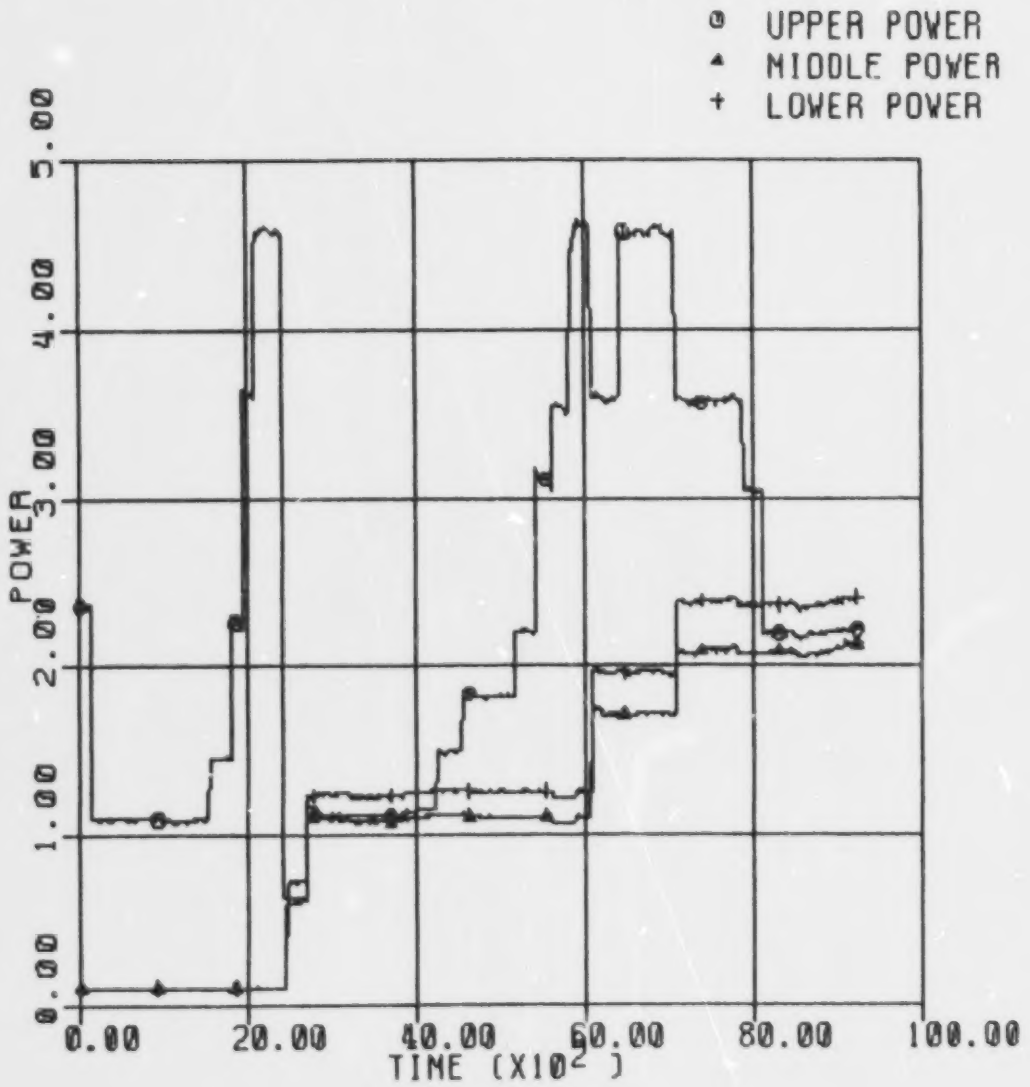

FIGURE 4.1-1

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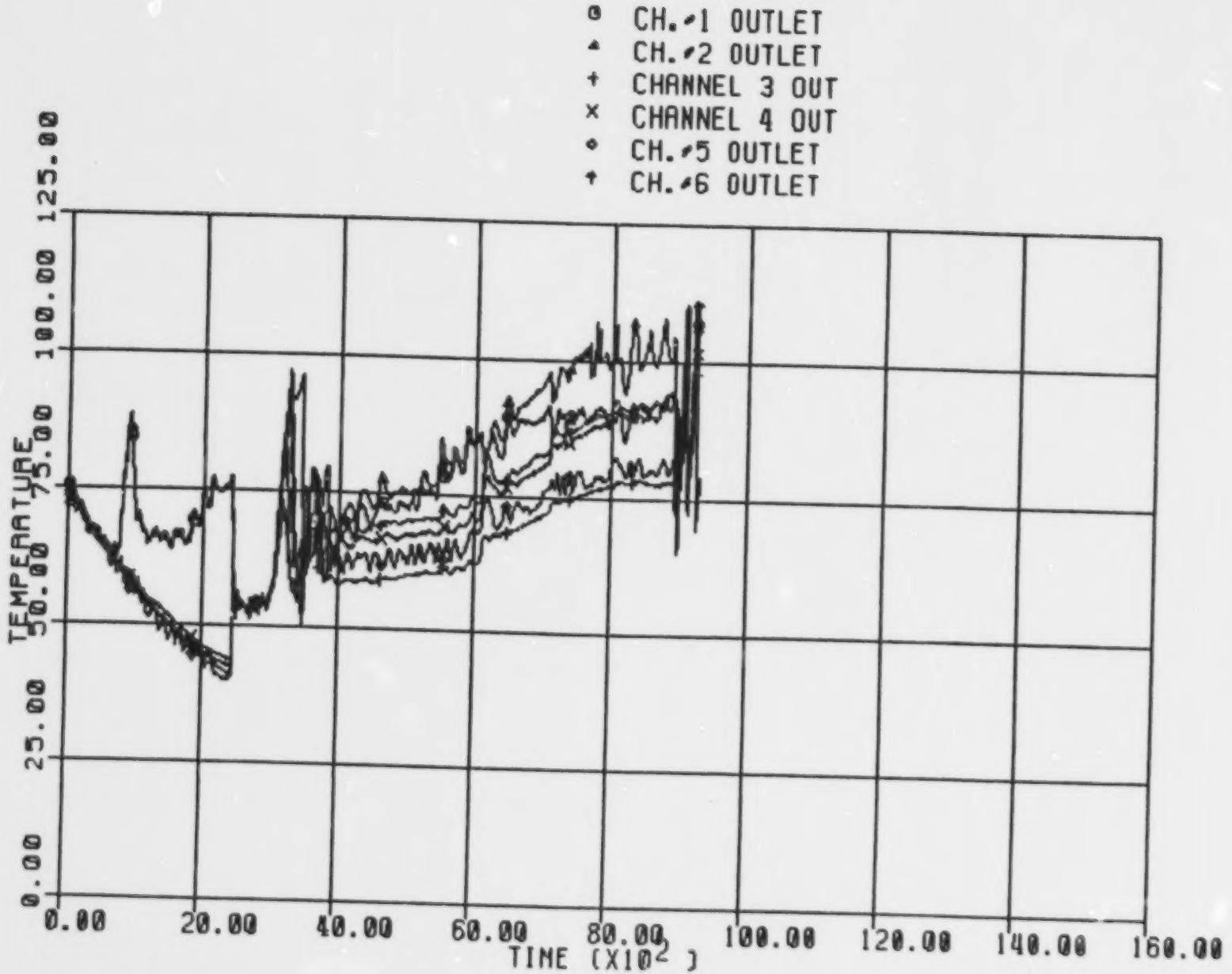

FIGURE 4.1-2

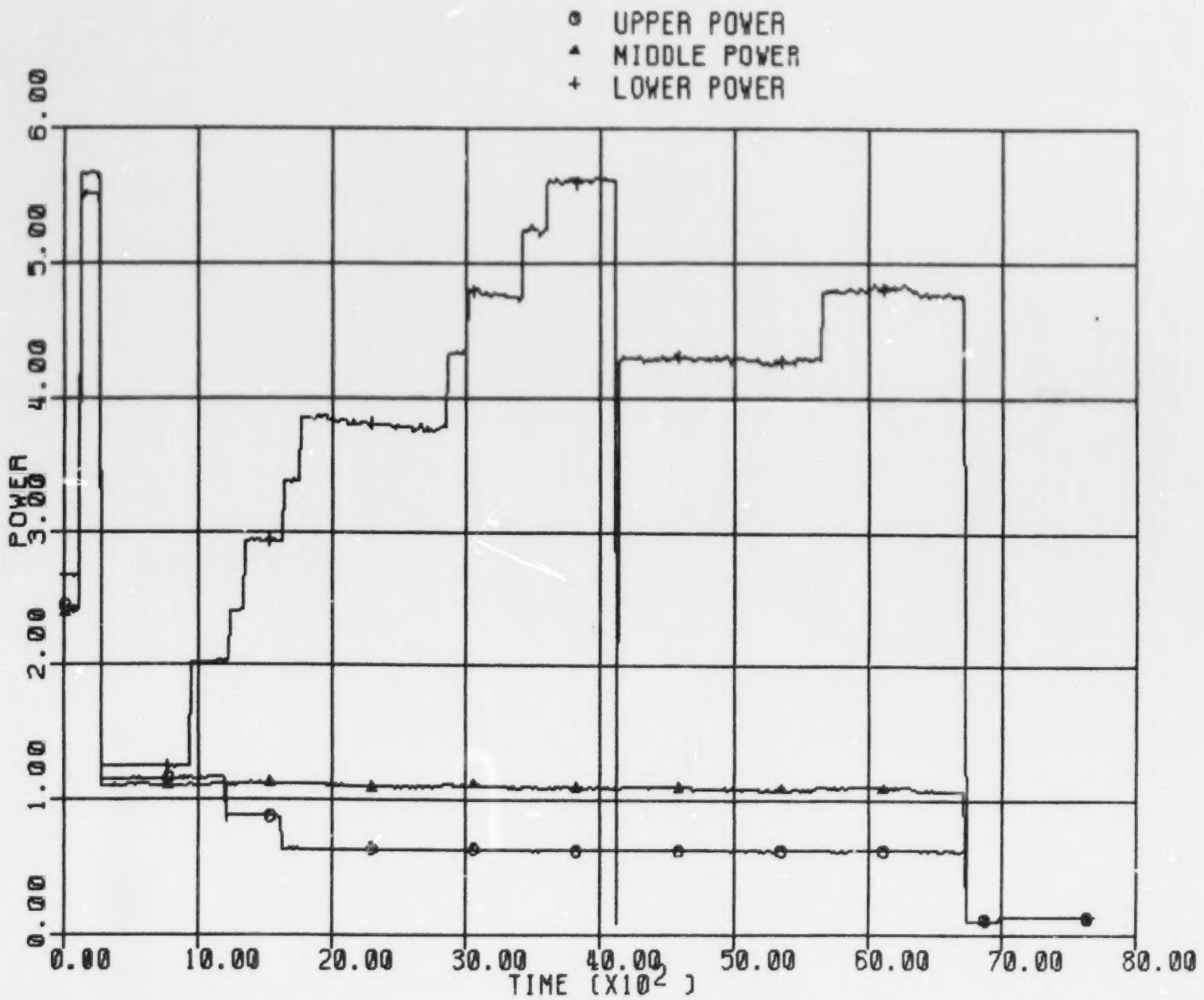
UPPER POWER
MIDDLE POWER
LOWER POWER
POWER
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
TIME (X10²)

FIGURE 4.1-3

AUG24001

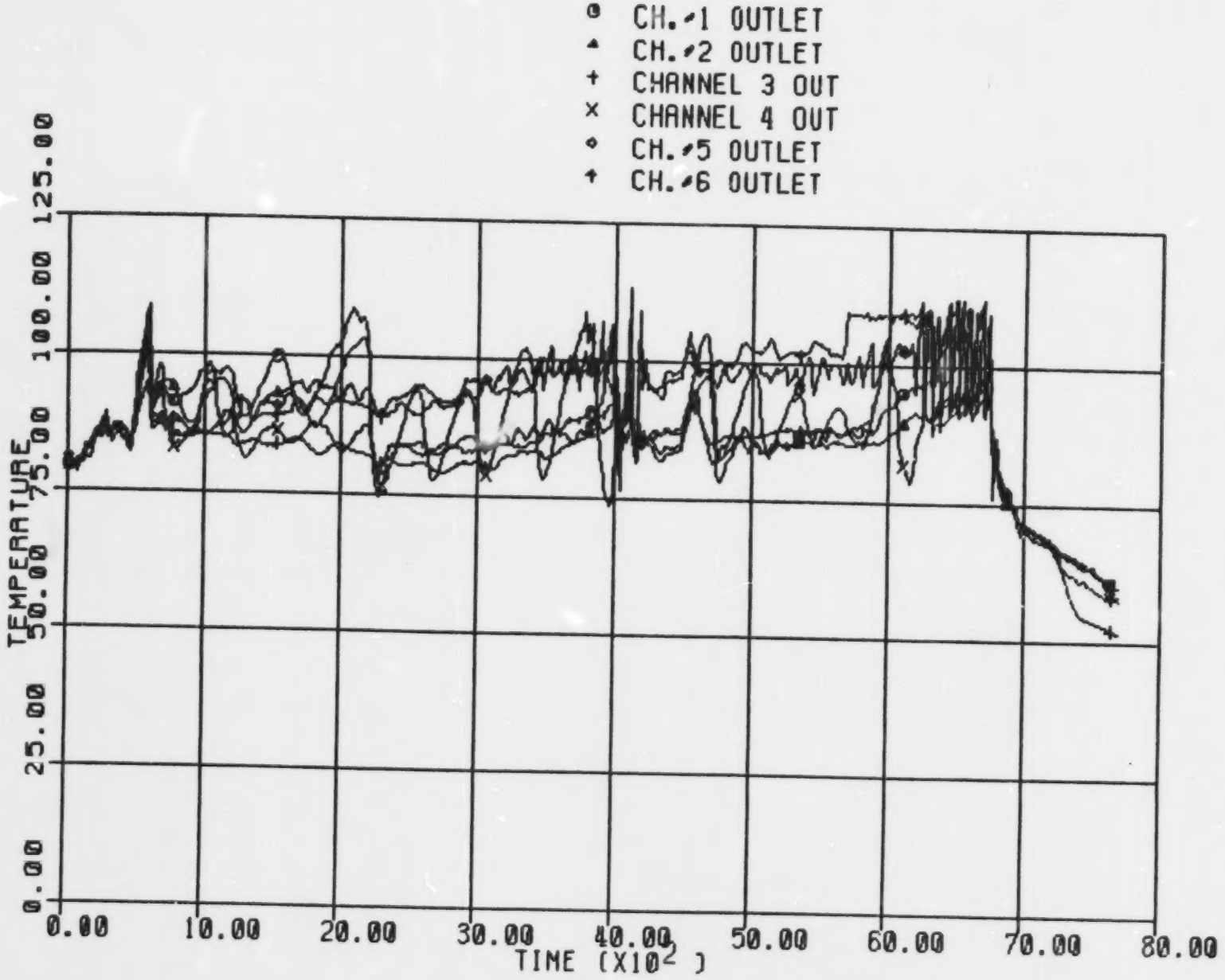

FIGURE 4.1-4

Figures 4.1-3 and 4.1-4 show the results of a similar experiment performed to determine the power threshold for boiling in the lower two channels. Power was raised in steps in the lower channels to 3.8 kW at 1800 s. The upper and middle circuits had powers of 0.7 kW and 1.1 kW respectively. At 2000 s, channel 1 boiled and stagnated. Flow in channels 1 and 2 reversed after this time. This experiment showed that the upper channels cannot be kept from boiling when overall rig power is raised. When total power is raised, inlet enthalpy increases for all the heated channels and all channels get closer to boiling conditions. The upper channels have the lowest flow due to lower gravity head, and thus these channels boil first. The treshold to boiling experiments showed that when the system is allowed to heat up uniformly, channels 1 and 2 will reach the boiling condition first because of their lower flows.

4.2 Pump Trip Tests

These tests were done to determine the power required to cause channel boiling following a pump trip. The tests were done by operating the rig hot with the pumps running at reduced speed, and then tripping the pumps. The same initial conditions were used for each test. Conditions in the rig at the start of each test were:

Boiler outlet T = 70° - 75°
Feedwater flow = .02 kg/s
Channel ΔT = 2° - 5°

Once the desired starting conditions were attained, the power controls were set to the desired positions and the pumps were shut off.

4.2.1 Equal Channel Powers

The first pump trip tests were done with equal powers in all the heated channels. Figures 4.2.1-1 to 4.2.1-5 show results for a pump trip test with all power control dial

positions set at 0.5. The total rig power following pump trip was 4.6 kW. Temperatures in the heated channels stay below 100°C throughout the test as shown in figure 4.2.1-2 and natural circulation flow remains forward in all channels as shown in figure 4.2.1-3.

Figures 4.2.1-6 to 4.2.1-11 show the results of a pump trip test with all power controls set at 0.7, giving a total rig power of 9 kW after the pump trip. Boiling occurs at 125 s as shown in figure 4.2.1-7. The boiling stops by about 250 s, and stable single phase flow develops after this time. Figure 4.2.1-8 shows the flow pattern after the system passes through the boiling phase. By 300 s, flow has reversed in channels 1 and 4, and channels 2, 3, 5 and 6 continue to flow in the forward direction. The relative flows in the system could be obtained from temperature measurments during the transients.

At 700 s, boiler outlet temperature was 58.5°, channel 4 inlet temperature was 93.5° and the average inlet temperature for channels 2 and 6 was 69.1°. These temperatures are shown in figure 4.2.1-11. Water flowing into channels 2 and 6 comes partially from channel 4, and partially from the boiler. The inlet header temperature was 69.1°, and therefore the ratio of forward flow through the boiler to reverse flow in channel 4 is

$$\frac{QB}{Q4} = \frac{93.5 - 69.1}{69.1 - 58.5}$$

$$= 2.3$$

where QB = boiler flow

Q4 = channel 4 flow

With two channels flowing in the reverse direction, flow through the boilers is reduced to that of two heated channels. The flow from the reversed channels bypasses the boilers and feeds directly into the forward flowing channels.

AUG28W03

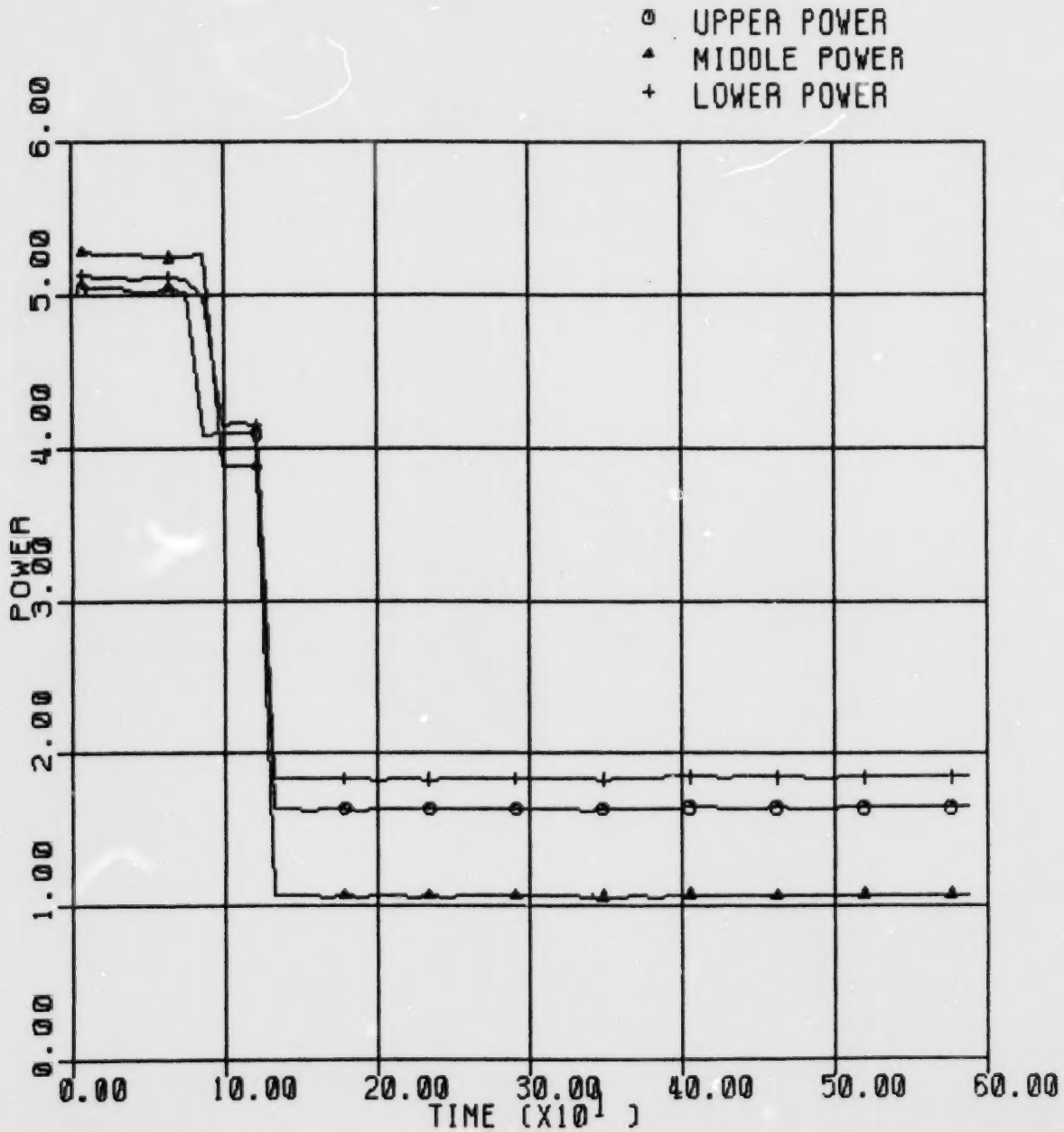

FIGURE 4.2.1-1

AUG28005

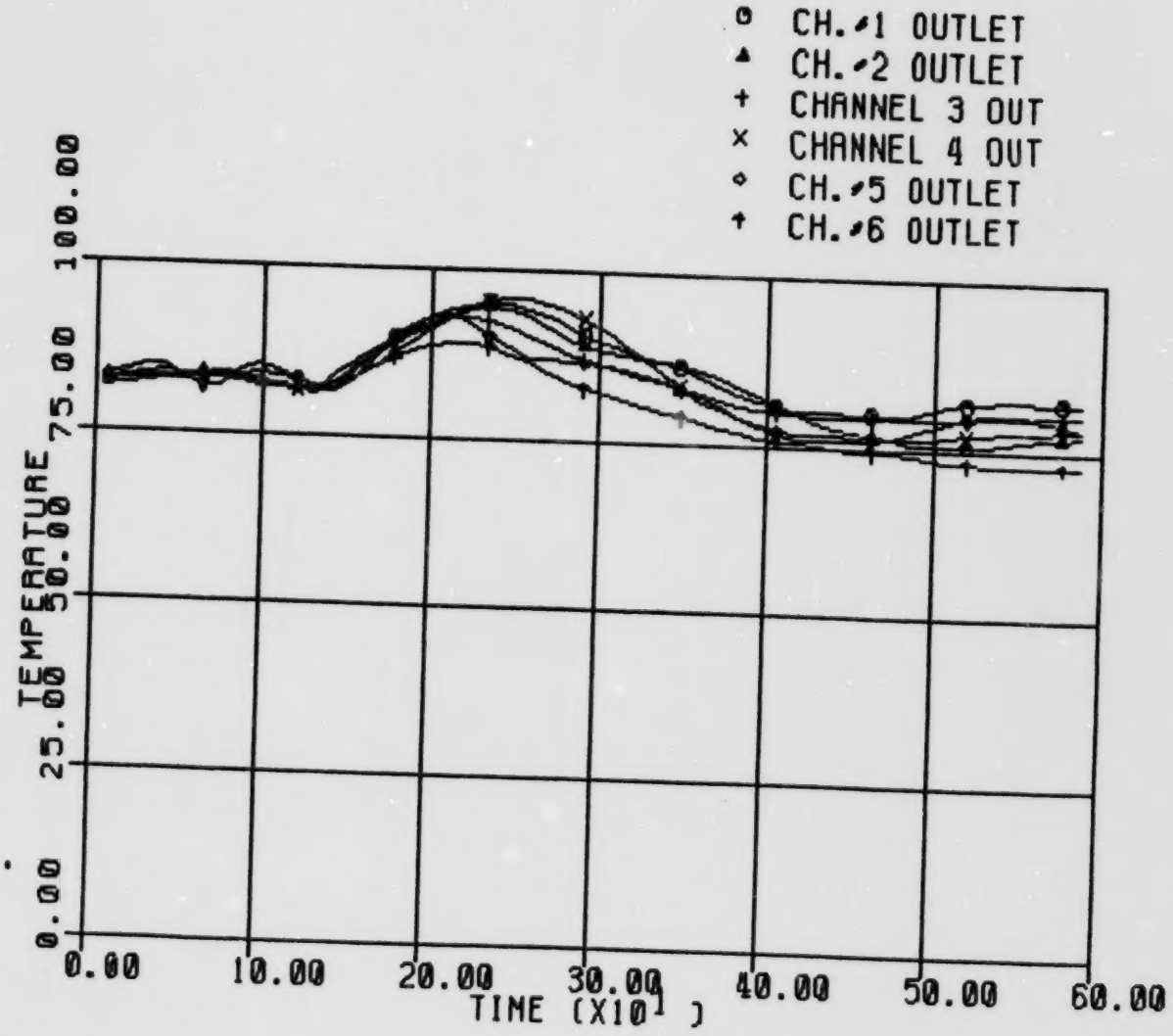

FIGURE 4.2.1-2

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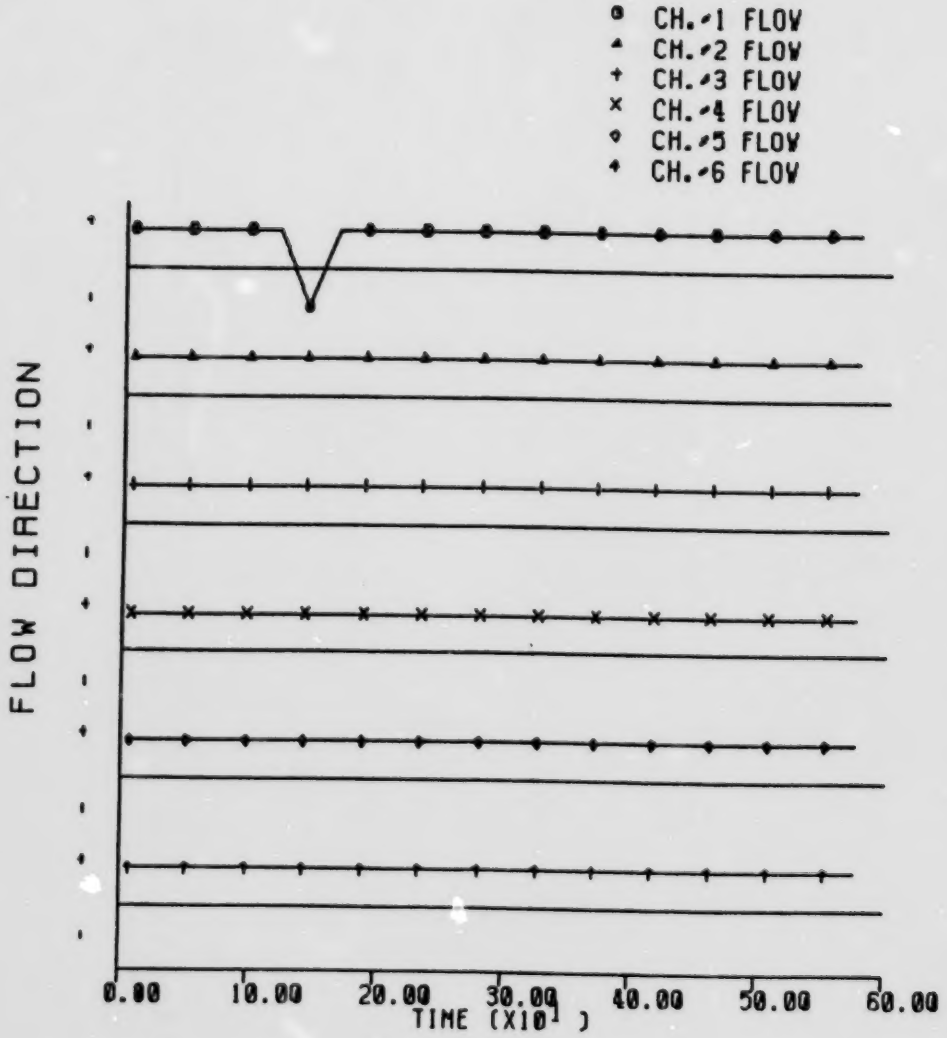

FIGURE 4.2.1-3

AUG28005

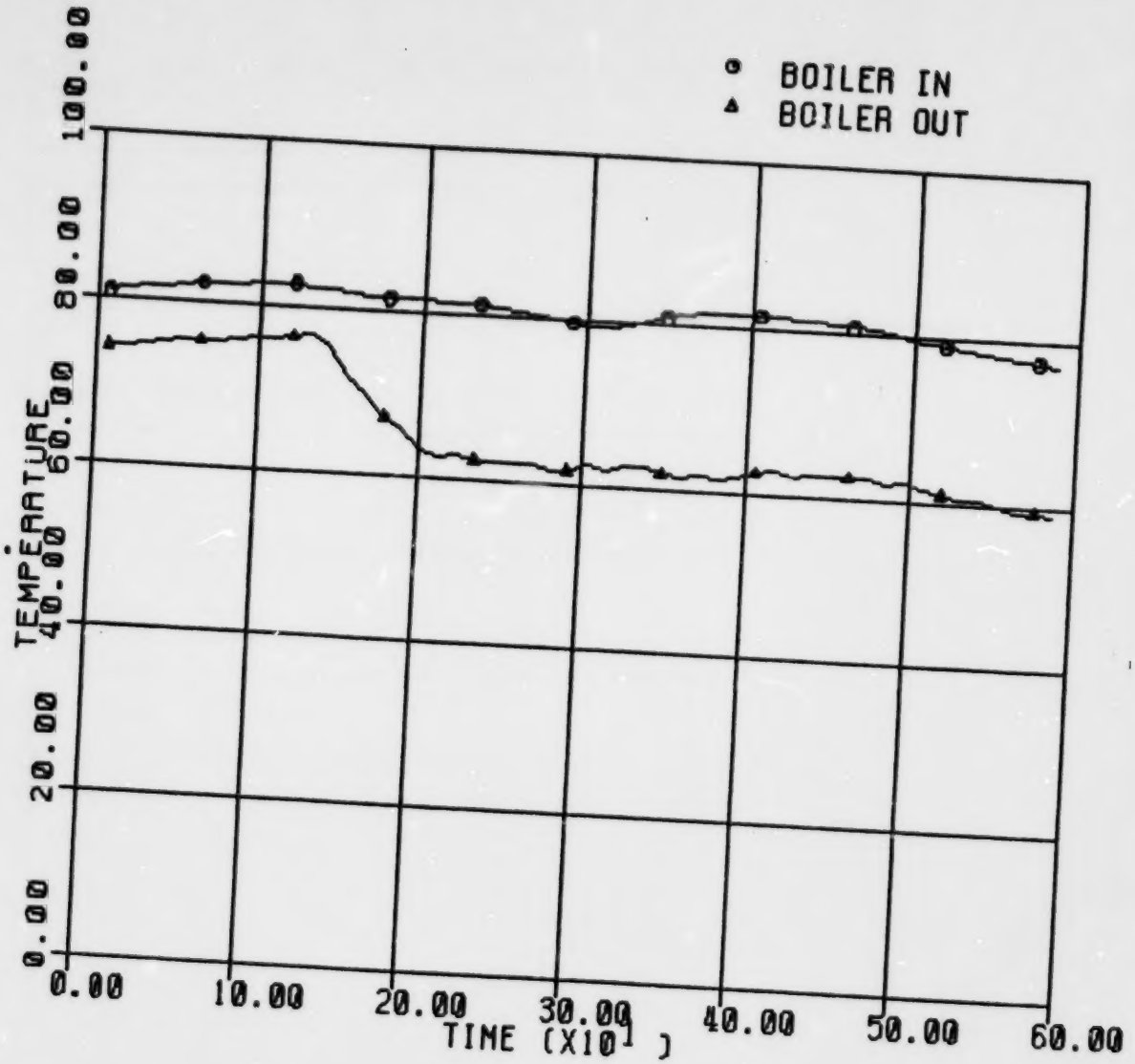

FIGURE 4.2.1-4

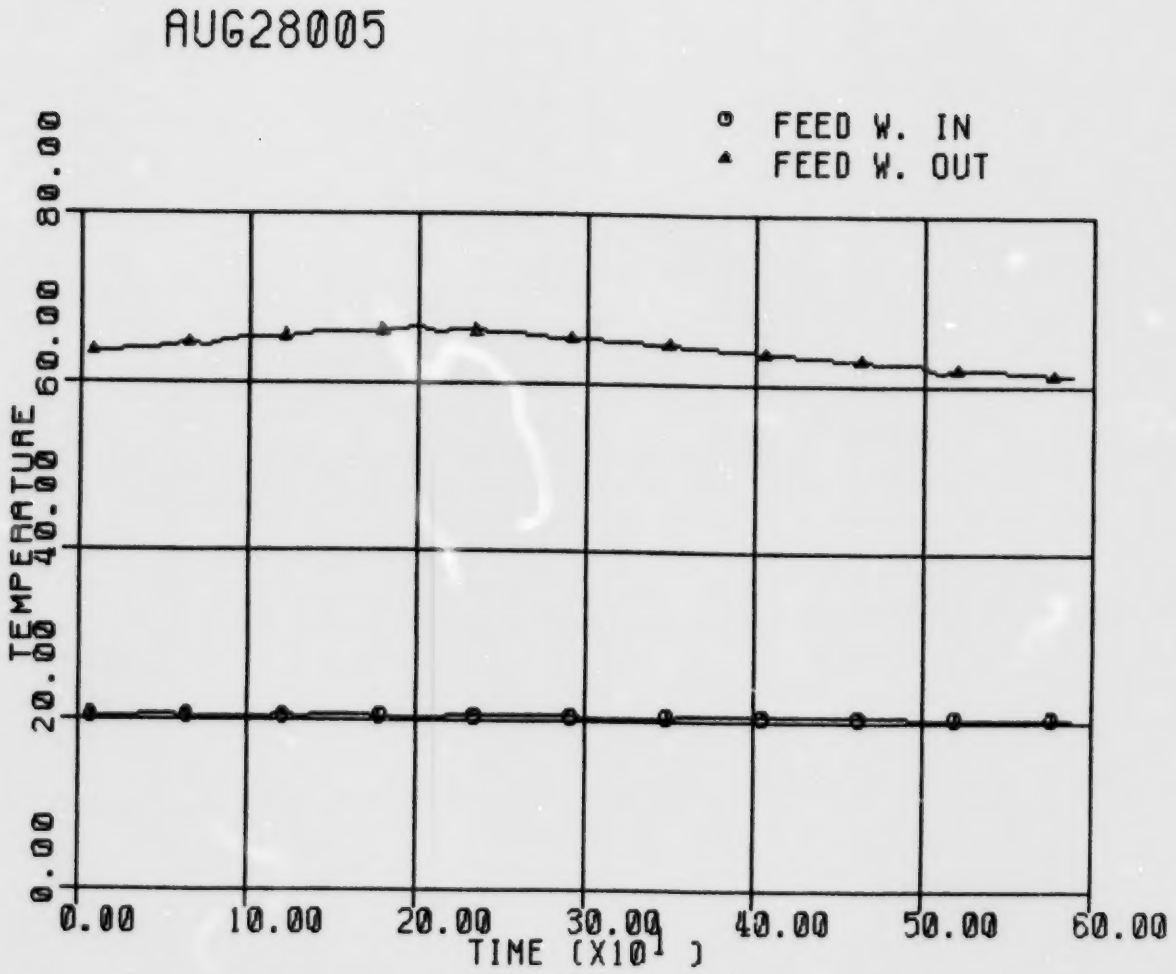
AUG28005
FEED W. IN
FEED W. OUT
TEMPERATURE
0.00
20.00
40.00
60.00
80.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
TIME (X10)

FIGURE 4.2.1-5

AUG28008

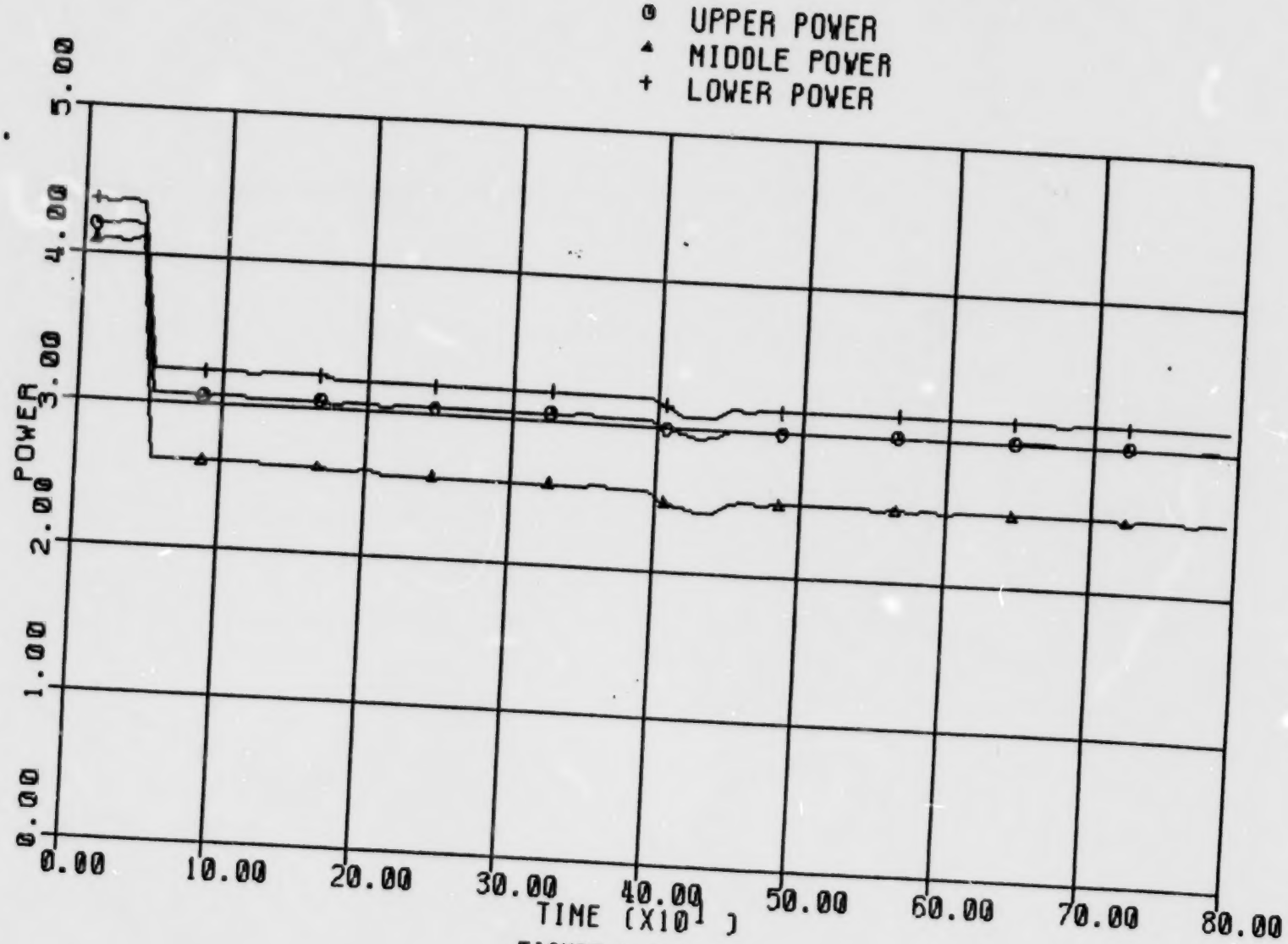

FIGURE 4.2.1-6

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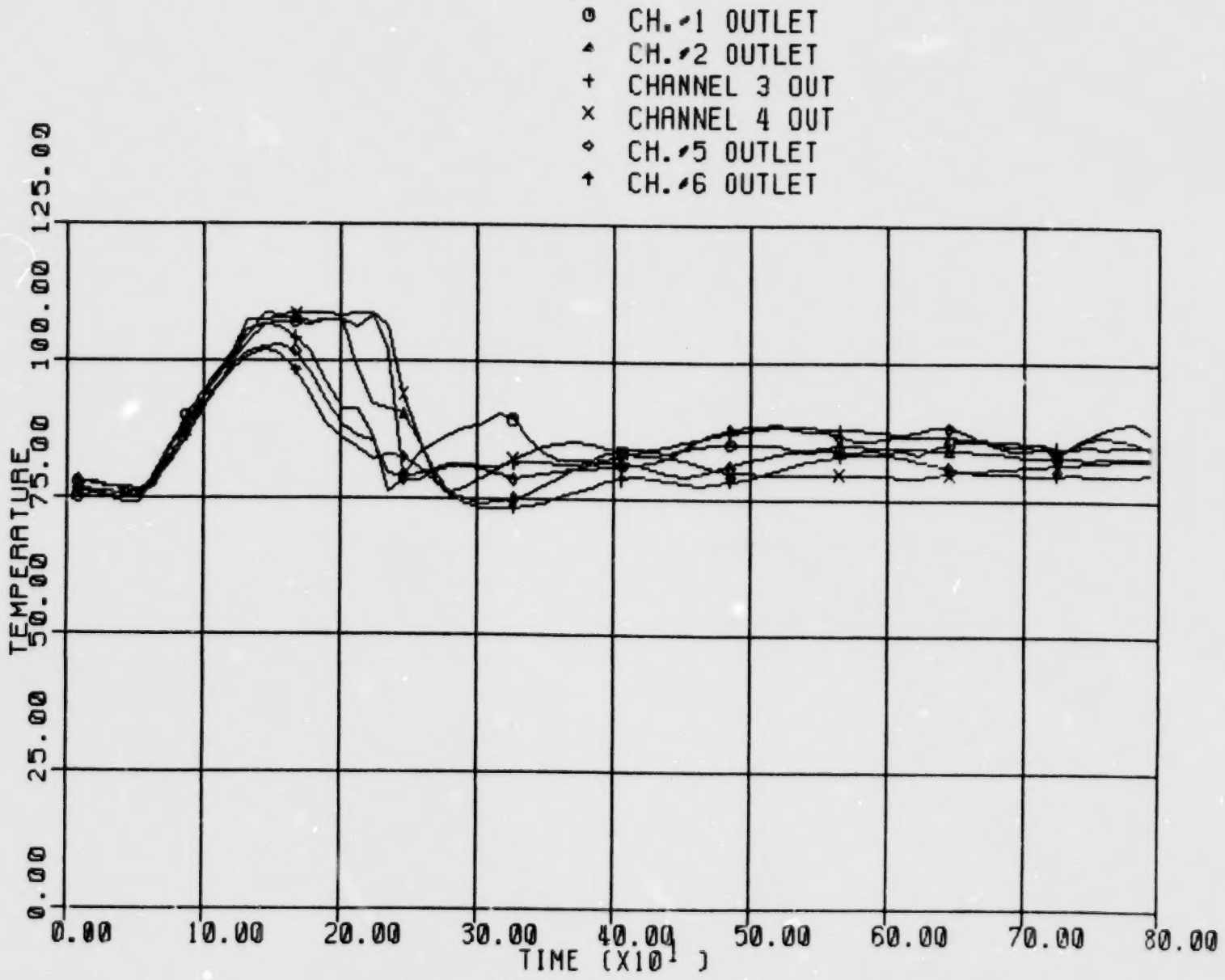

FIGURE 4.2.1-7

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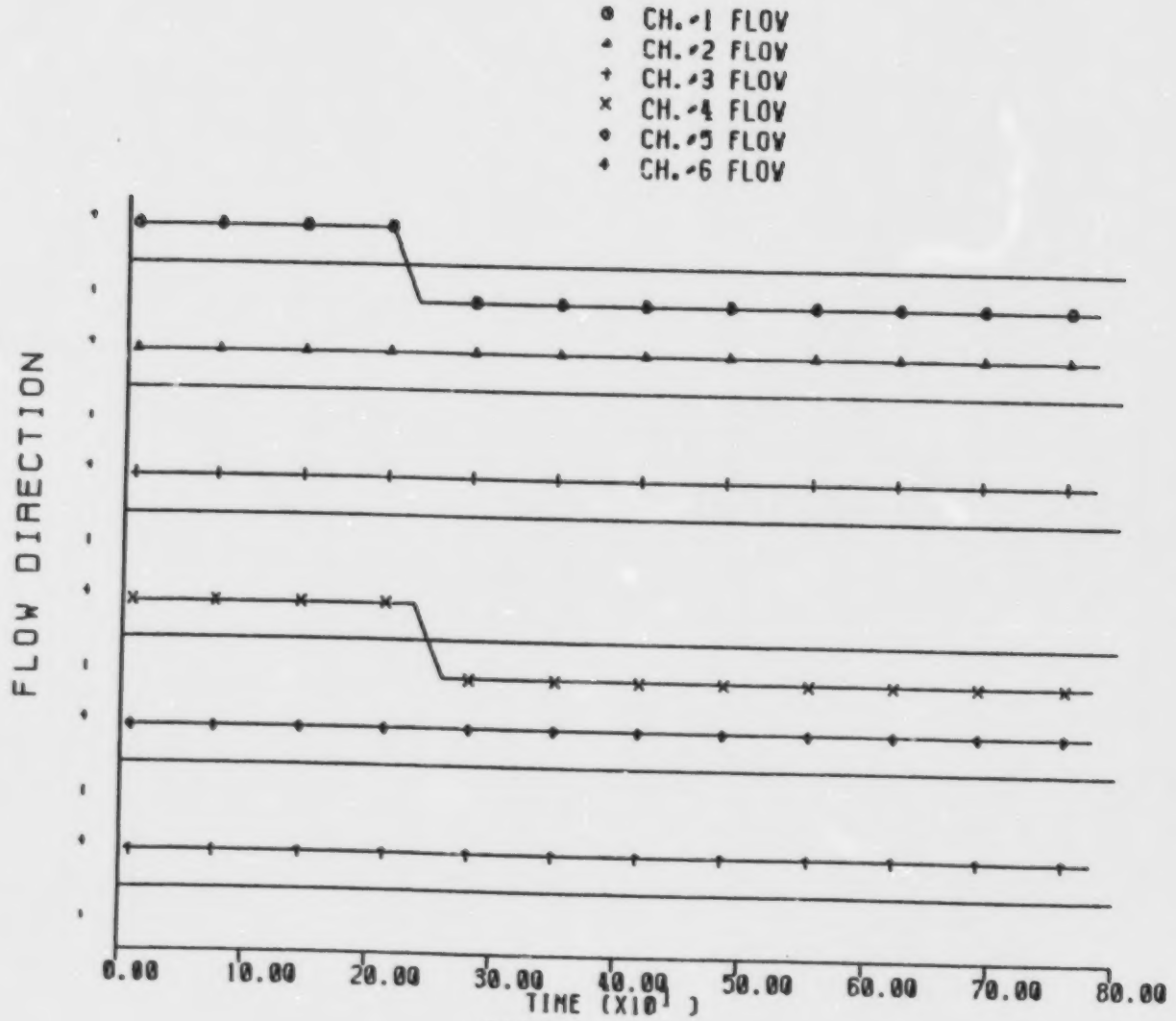

FIGURE 4.2.1-8

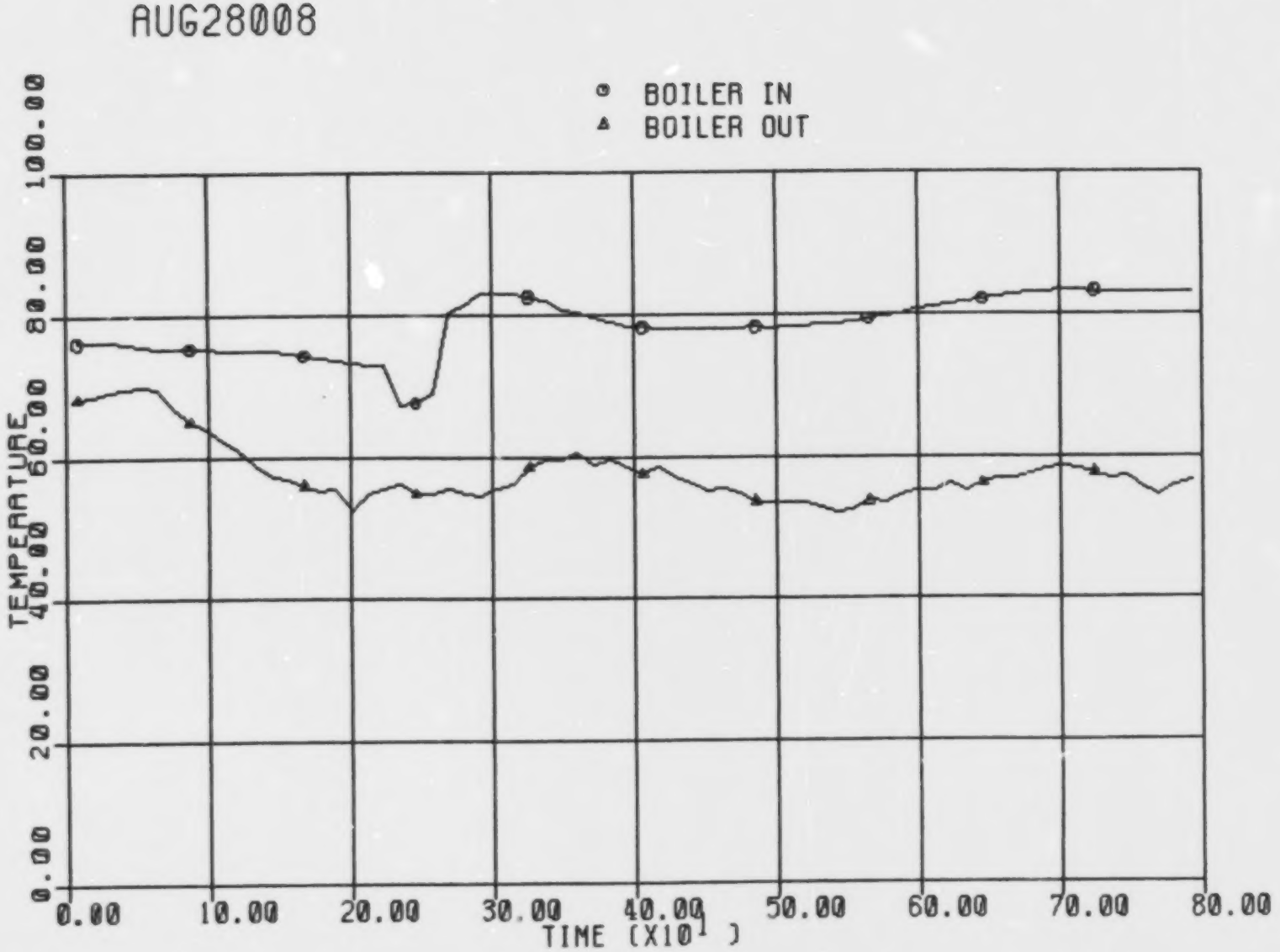
AUG28008
BOILER IN
BOILER OUT
TEMPERATURE
0.00
20.00
40.00
60.00
80.00
100.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
TIME (X10)

FIGURE 4.2.1-9

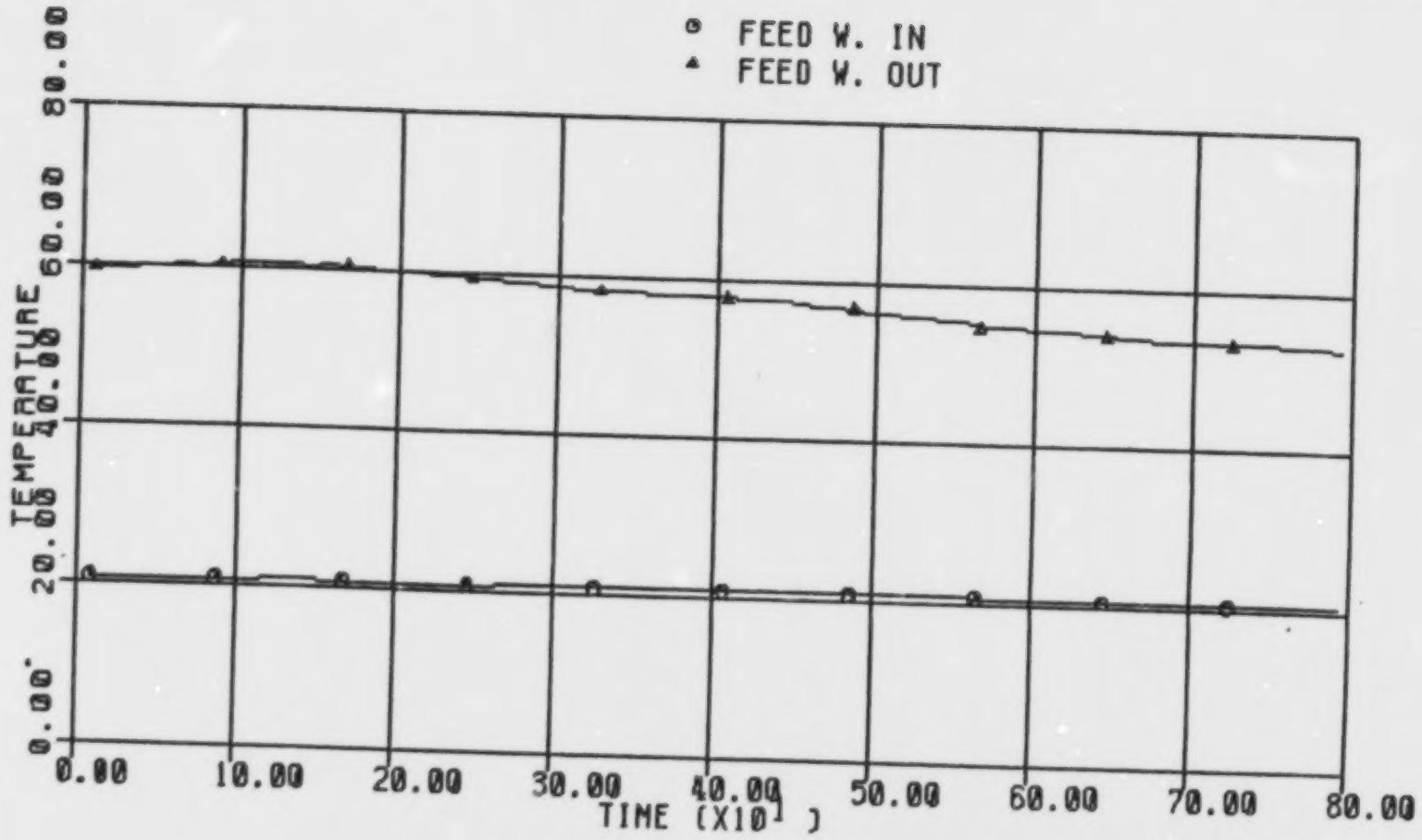

FIGURE 4.2.1-10

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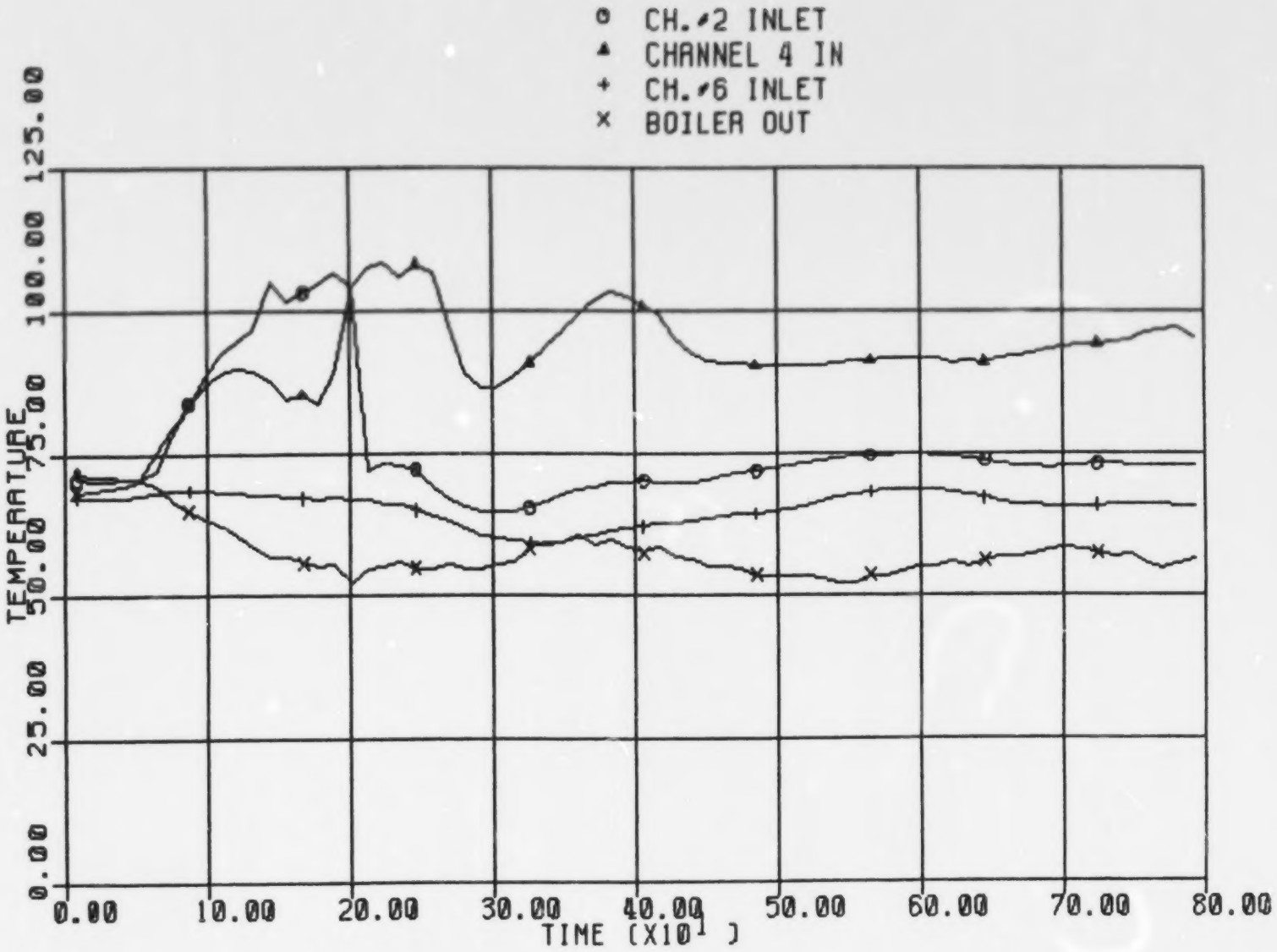


FIGURE 4.2.1-11

Following the period of boiling after pump trip, the flow pattern can stabilize in different ways. Figures 4.2.1-12 to 4.2.1-16 show the results from a test conducted in the same way as the previous test. As shown in figure 4.2.1-14, flows stabilize with channels 1 and 2 in the reverse direction and channels 3 to 6 flowing in the forward direction. The pattern of one reverse flowing channel in each core pass was a common outcome of all tests where the rig went through a boiling transient. Other observed outcomes included all channels flowing forward, and one channel forward and two channels reversed in each core pass. The latter outcome also had reverse flow through the boilers.

4.2.2 Unequal Channel Powers

The tests conducted on August 30 and 31, 1984 were done to investigate the effects of different heated channel power distributions on the outcome of a pump trip transient followed by natural circulation cooling.

Figures 4.2.2-1 to 4.2.2-5 show results of a pump trip test with channels 3 and 4 at higher power than 1 and 2 or 5 and 6. Figures 4.2.2-6 to 4.2.2-10 show results for a case with the upper circuit at higher power and figures 4.2.2-11 to 4.2.2-15 show the outcome of a test with channels 5 and 6 at higher power.

In each of the tests, the heated channels with high power began to boil first. The case with channels three and four at high power showed different behaviour than that for the tests with the other pairs of channels at high power. Figure 4.2.2-2 shows temperatures measured in the channels during the test. Following the pump trip, channels 3 and 4 began to boil at 100 s. By 150 s, channel 3 had flushed with flow in the reverse direction. Channel 4 continued to boil, with steam escaping from each end of the channel.

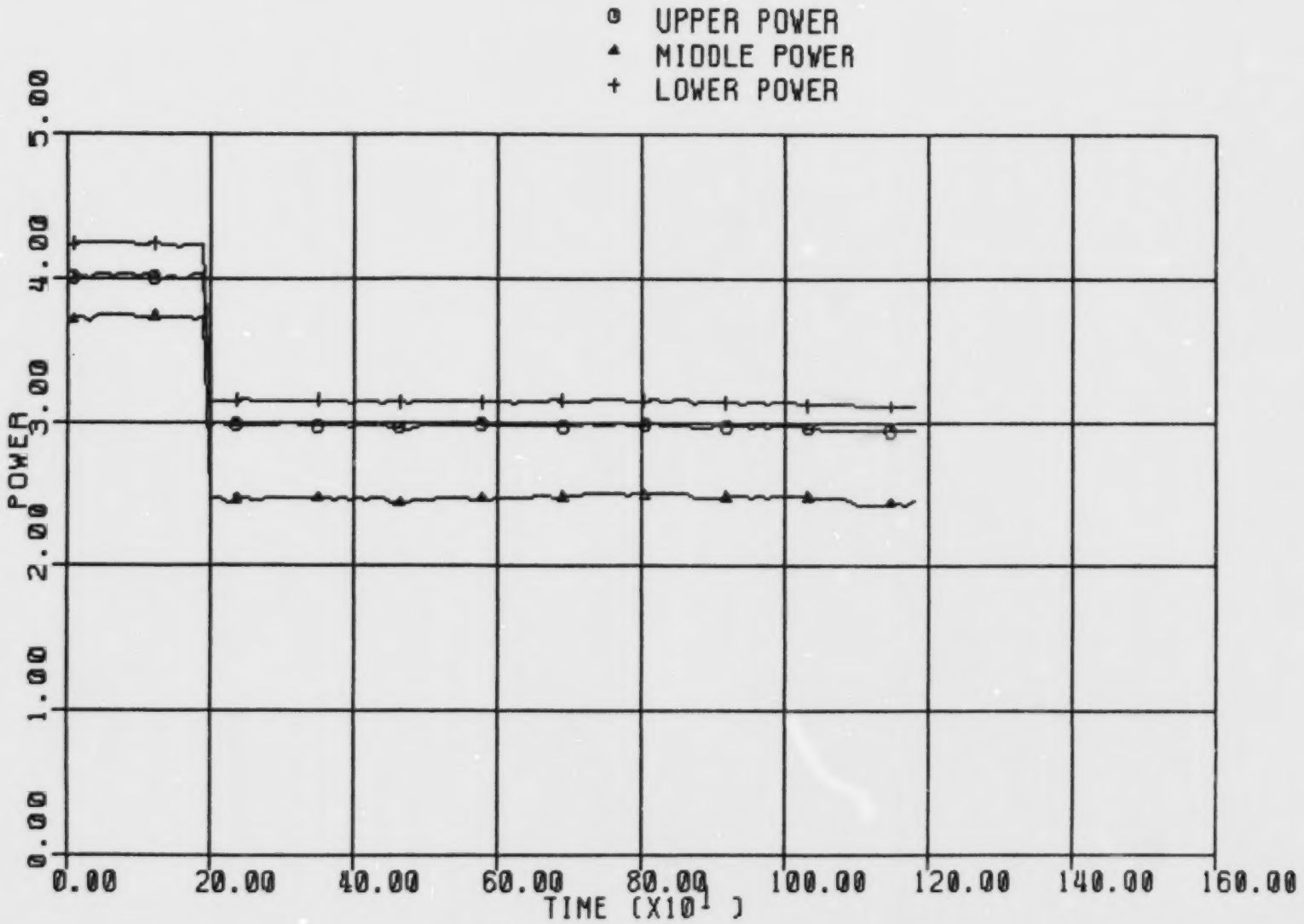


FIGURE 4.2.1-12

AUG30001

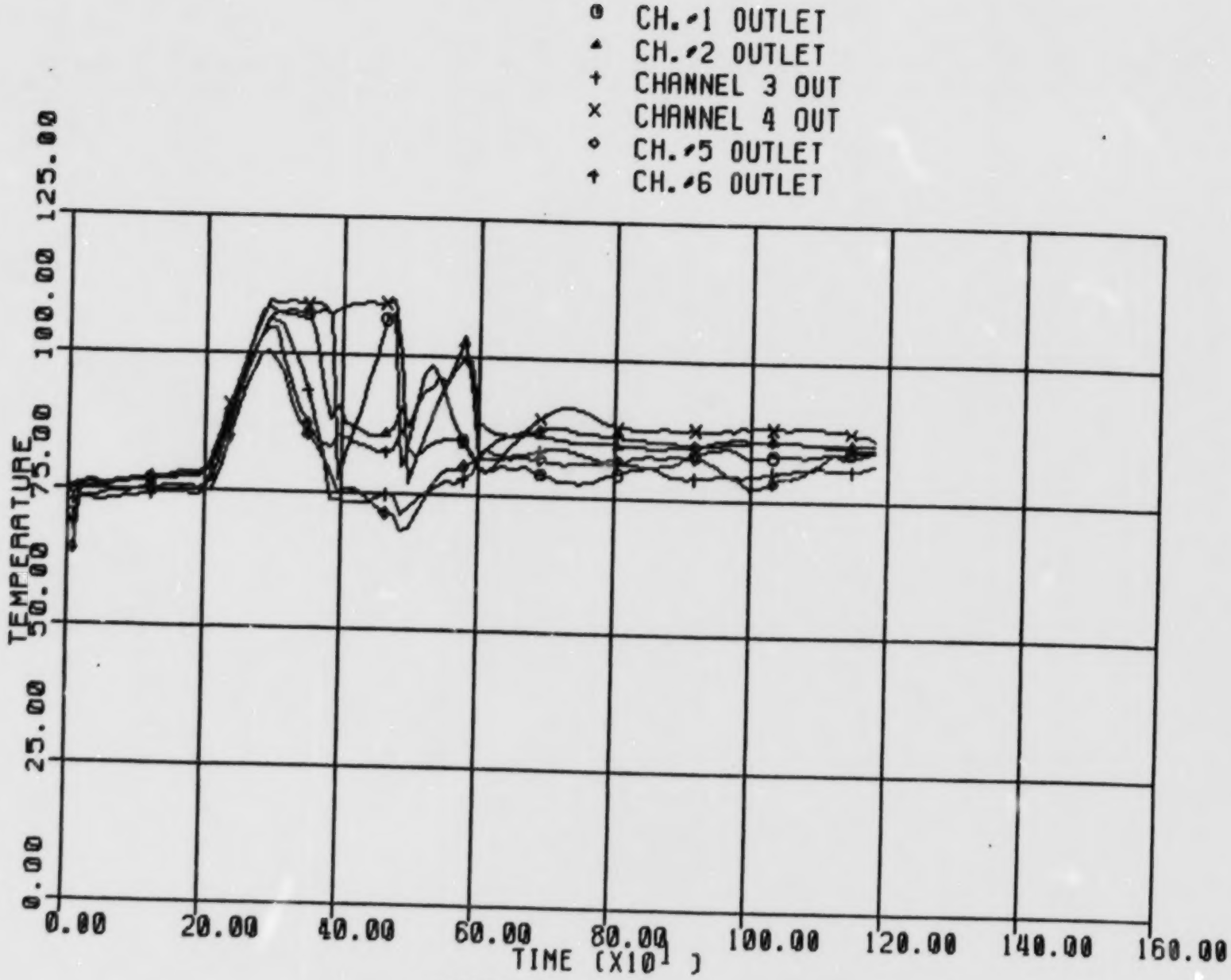


FIGURE 4.2.1.13

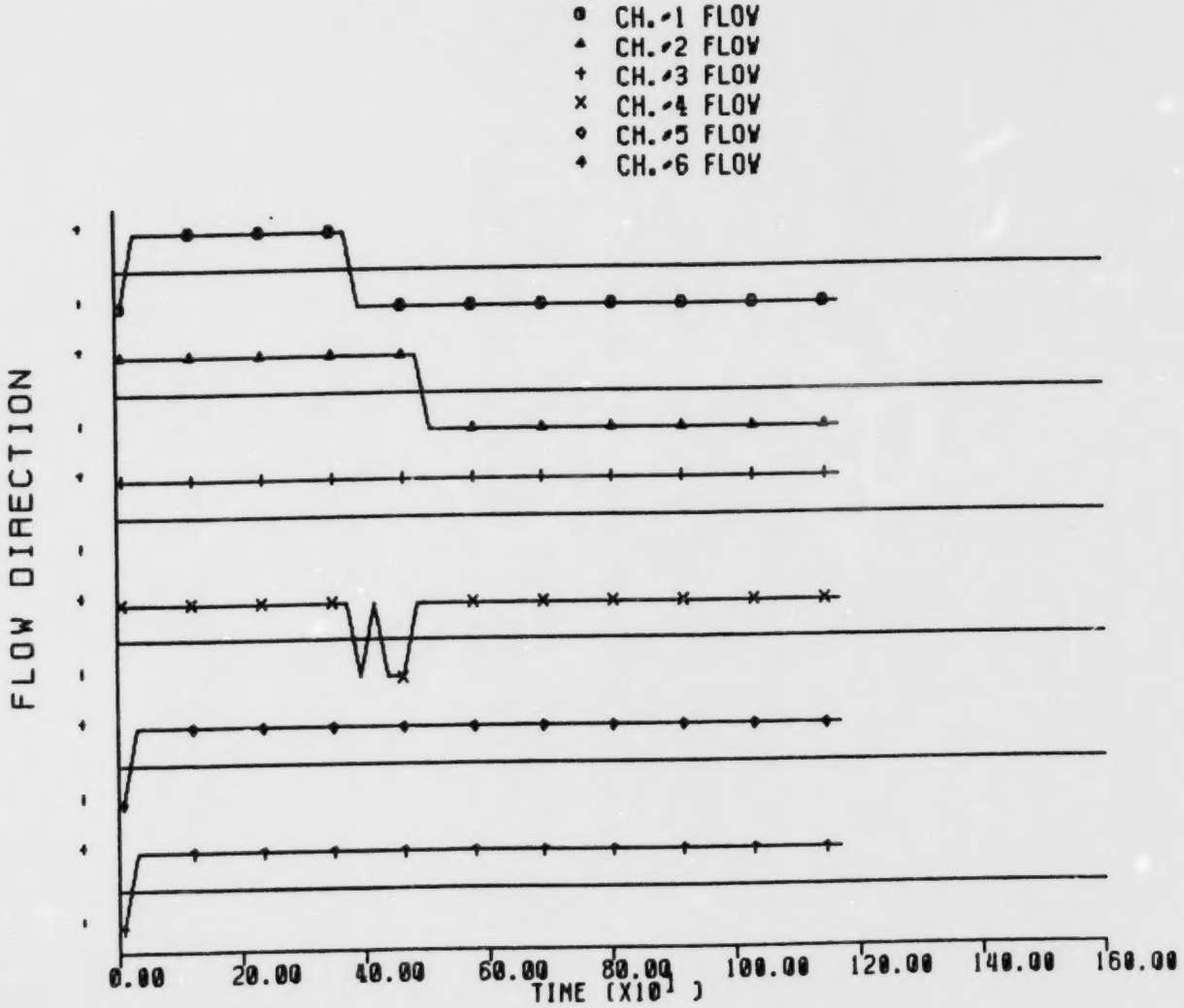


FIGURE 4.2.1-14

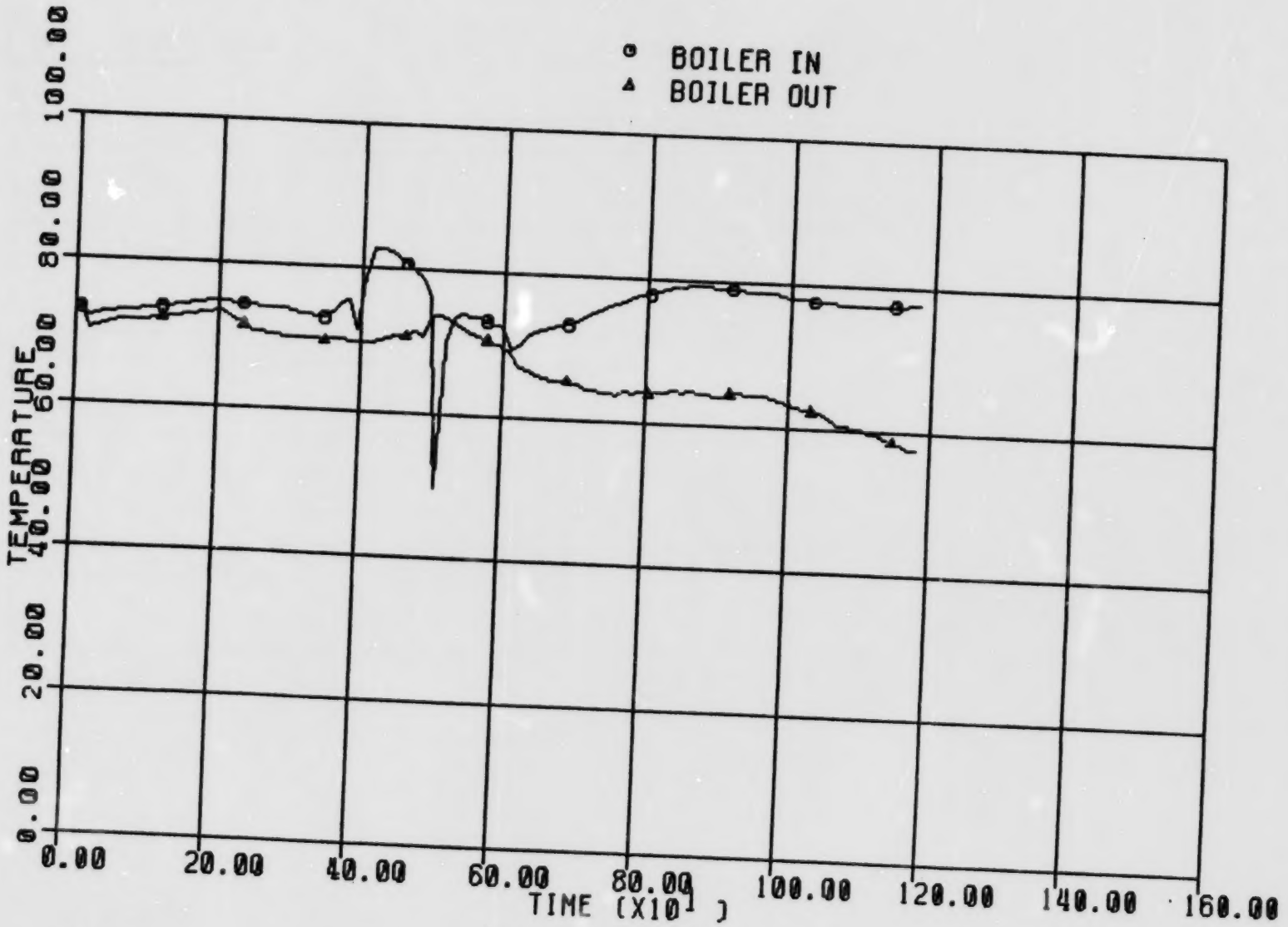


FIGURE 4.2.1-15

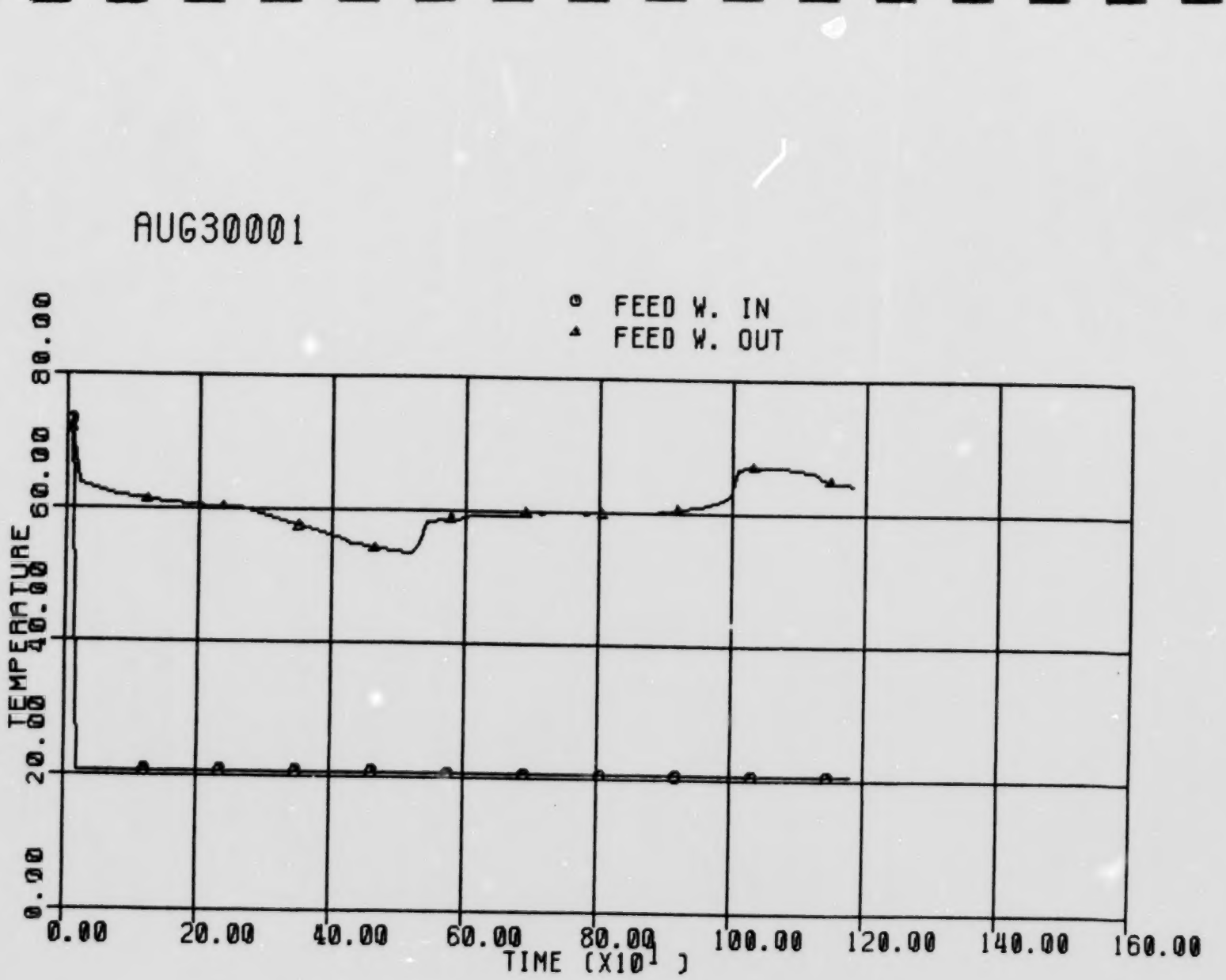


FIGURE 4.2.1-16

Eventually nearly all the water was evaporated from the channel and heater element temperature began to rise. As shown in figure 4.2.2-2, a maximum temperature 170° was reached. Power was shut off at this time to prevent damaging the channel. For tests with the upper and lower channel pairs at high power, long periods of flow stagnation such as that seen in channel 4 were not observed. The test with the upper circuit at high power caused boiling at 220 s (figure 4.2.2-7) followed by flushing of the upper channels. The flow reversed in channels 1 and 4 (figure 4.2.2-8), and forward flow continued in the other heated channels.

The observation of flow stagnation in channel 4 led to many repetitions of the same experiment to prove repeatability, and to attempt to identify the cause of the behaviour. The experiment proved to be repeatable, but sometimes channel 4 would re-fill before power had to be shut off to prevent damage. Figure 4.2.2-16 shows temperature in channel 4 for a pump trip test conducted in the same way as that which gave the high temperature shown earlier. As before, channel 4 stagnated and eventually nearly all the water was evaporated from the channel. Heater temperature increased as shown in the figure, but in this case water eventually flushed into the channel in the forward direction. The heaters were quenched and temperature rapidly dropped as shown in figure 4.2.2-16. See Section 6 of this report for additional comments.

Tests were done to examine the effect of channel inlet subcooling on observed channel 4 behaviour. The channel appeared to flush more rapidly when subcooling was reduced. Test AUG31001 was a pump trip test with high inlet subcooling (boiler outlet T = 50°). Figure 4.2.2-17 shows temperature in channel 4. Some boiling occurred, however no stagnation was observed and heater temperature did not rise significantly.

AUG30003

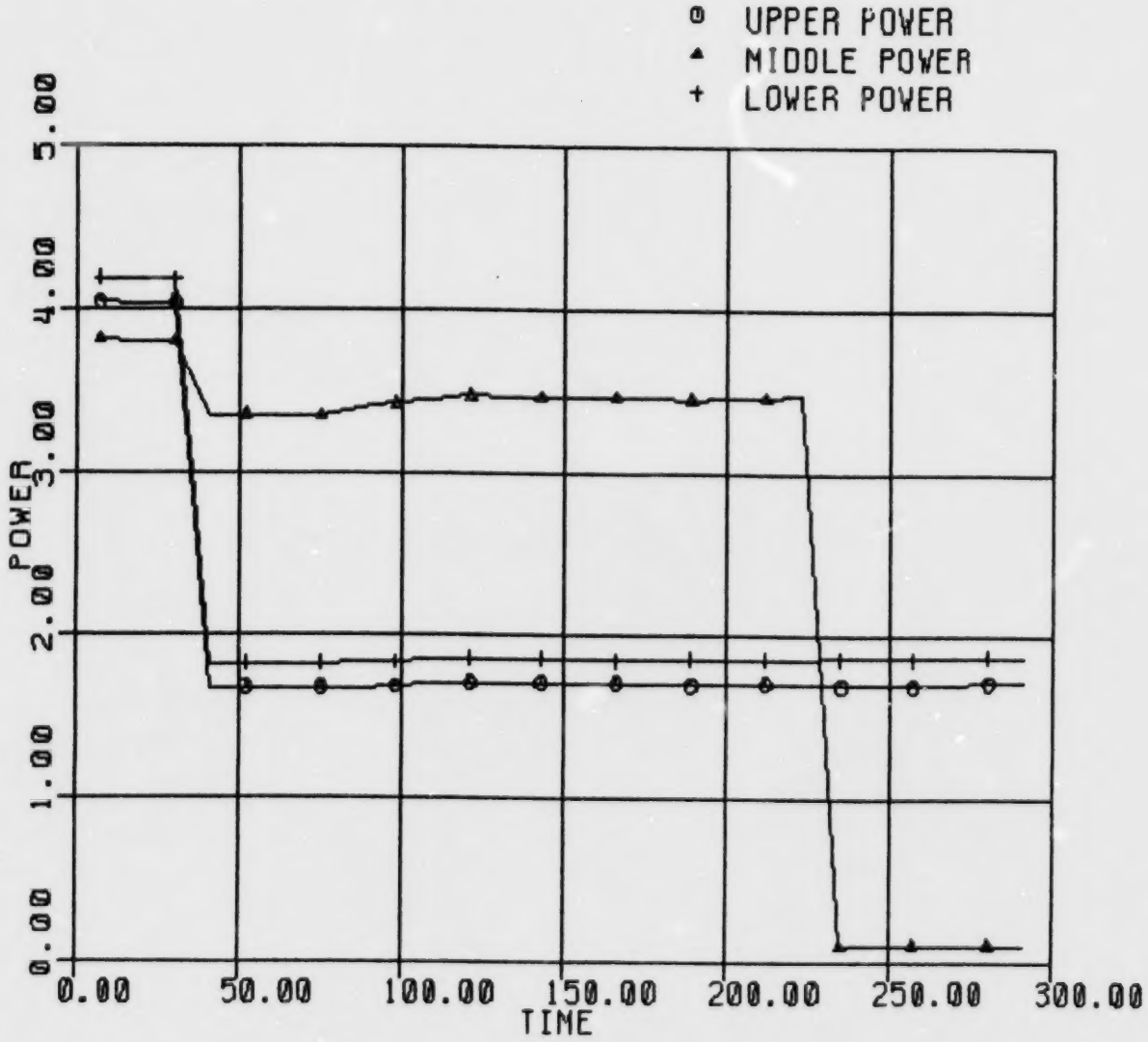


FIGURE 4.2.2-1

AUG30003

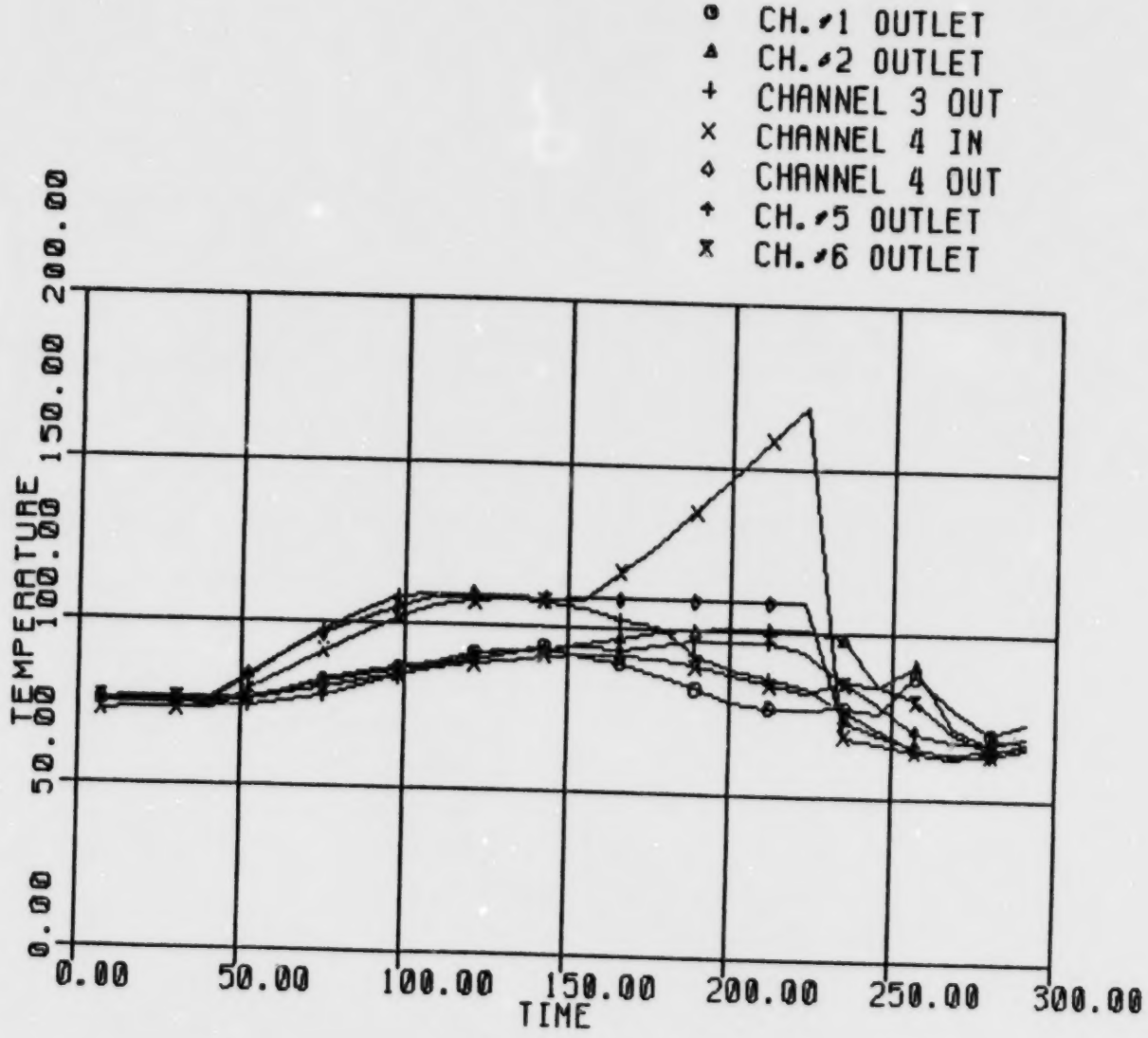


FIGURE 4.2.2-2

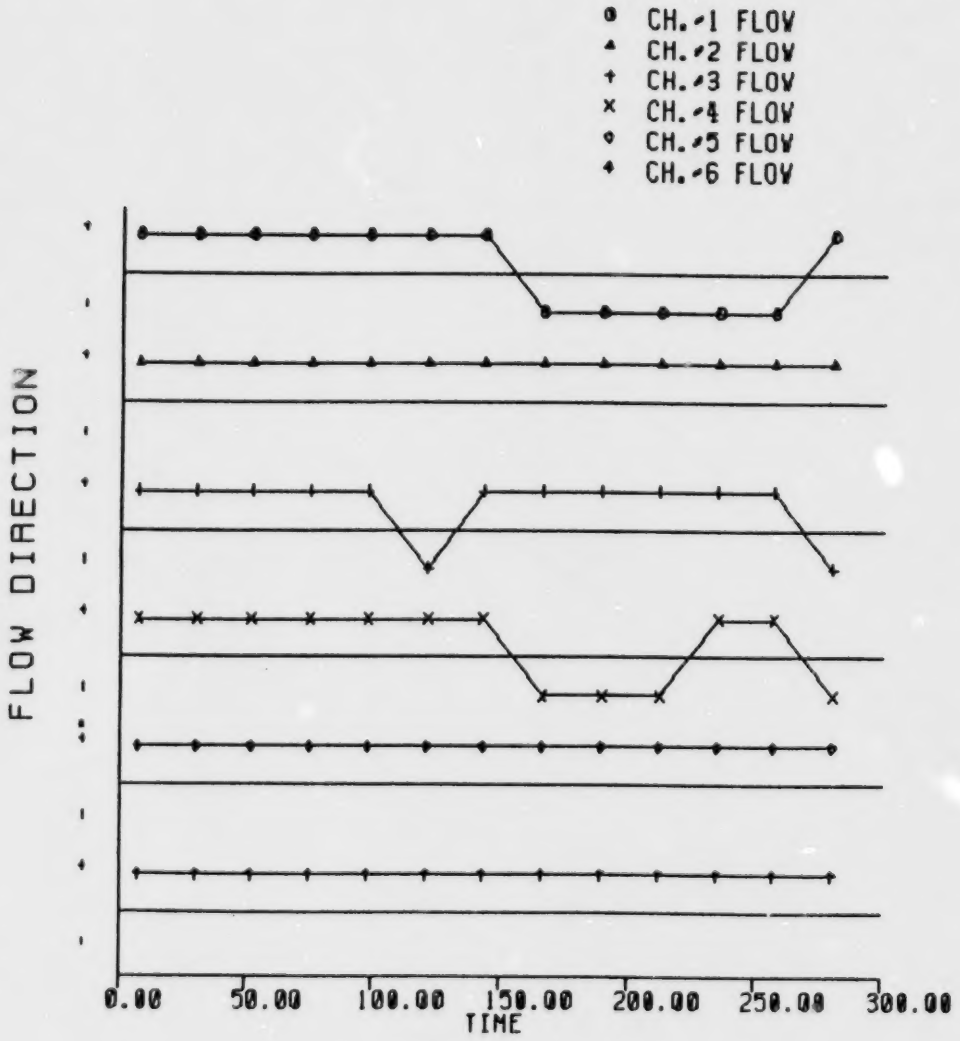

AUG30003
CH.#1 FLOW
CH.#2 FLOW
CH.#3 FLOW
CH.#4 FLOW
CH.#5 FLOW
CH.#6 FLOW
FLOW DIRECTION
0.00
50.00
100.00
150.00
200.00
250.00
300.00
TIME

FIGURE 4.2.2-3

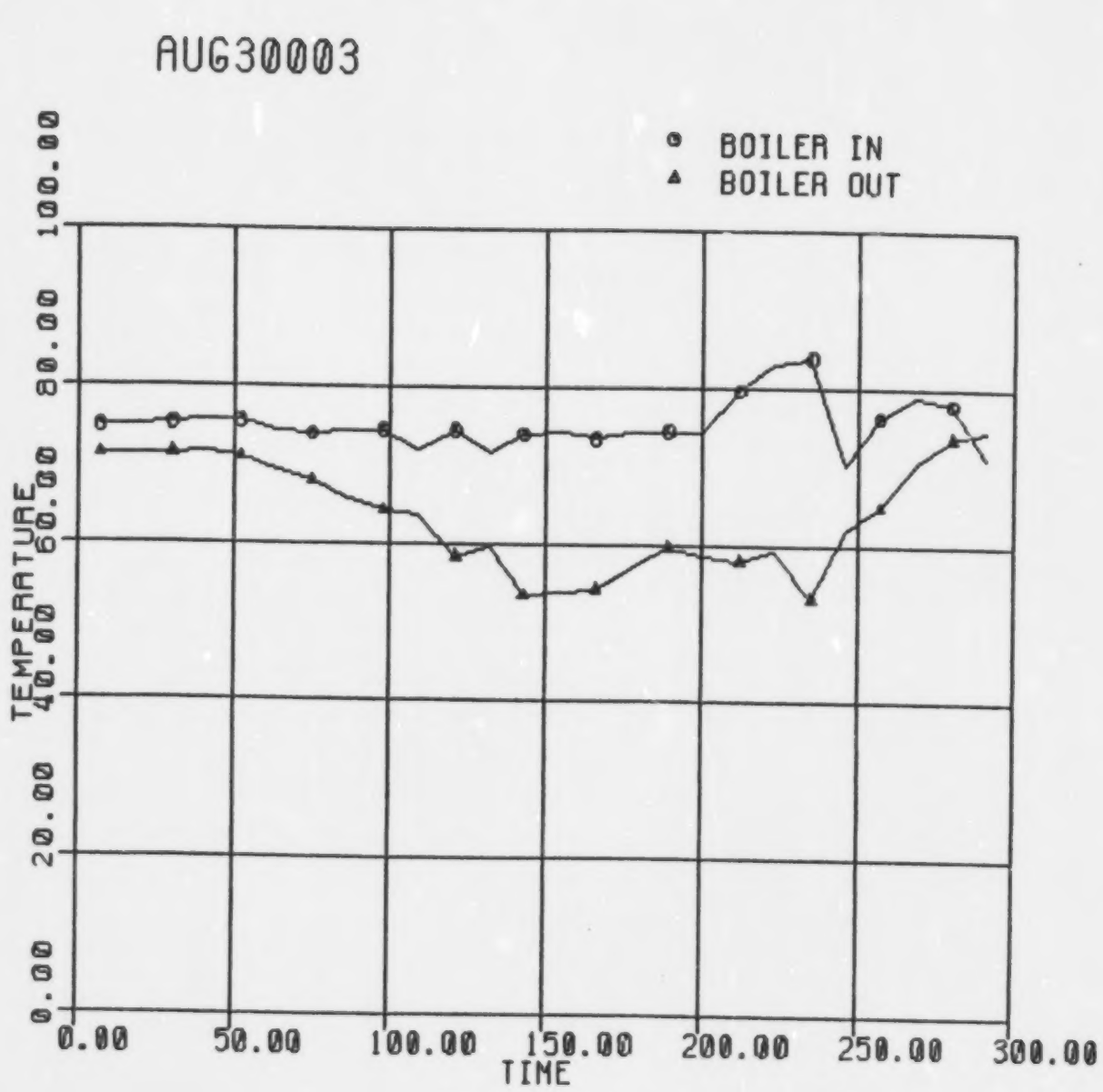

AUG30003
BOILER IN
BOILER OUT
TEMPERATURE
0.00
20.00
40.00
60.00
80.00
100.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
TIME

FIGURE 4.2.2-4

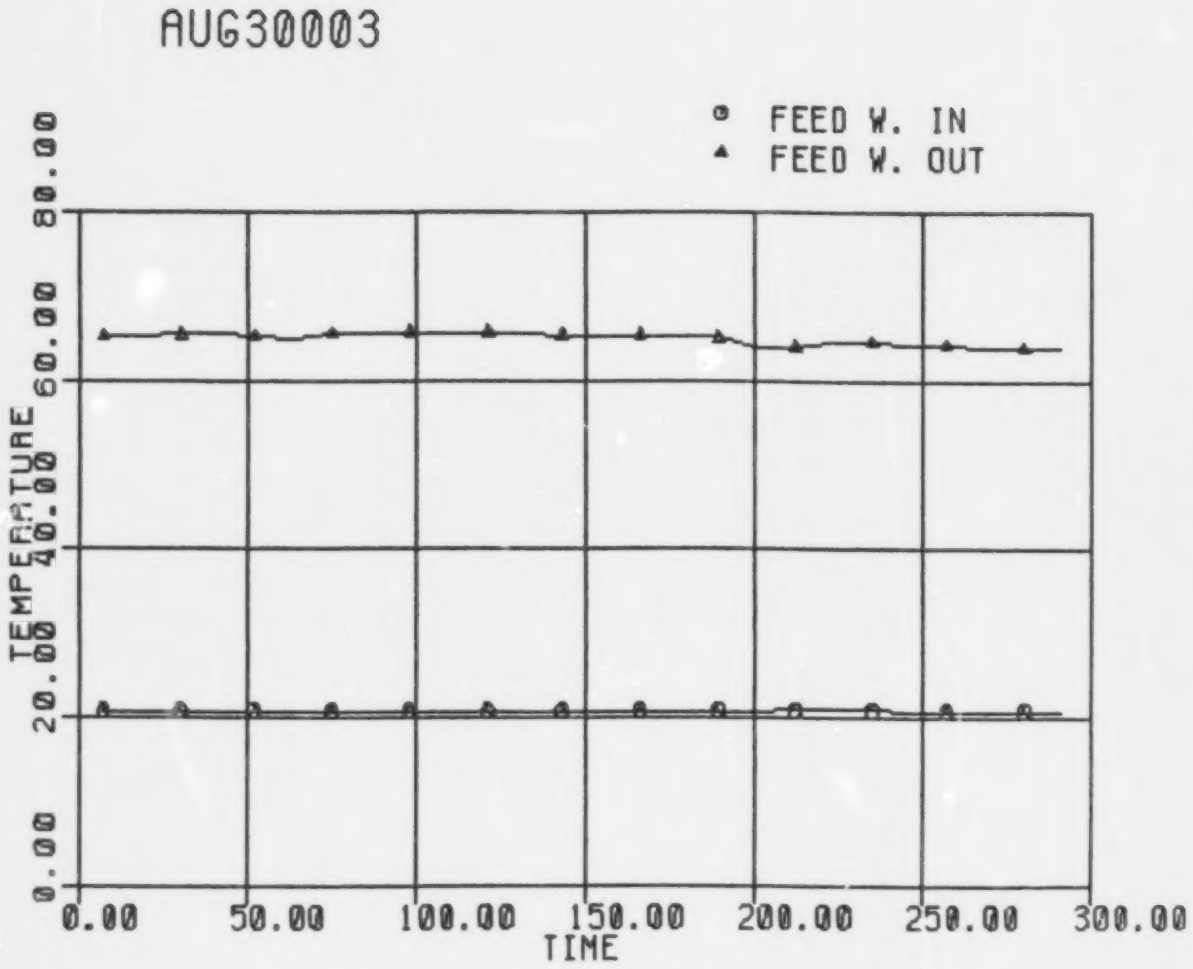

AUG30003
FEED W. IN
FEED W. OUT
TEMPERATURE
0.00
20.00
40.00
60.00
80.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
TIME

FIGURE 4.2.2-5

AUG30016

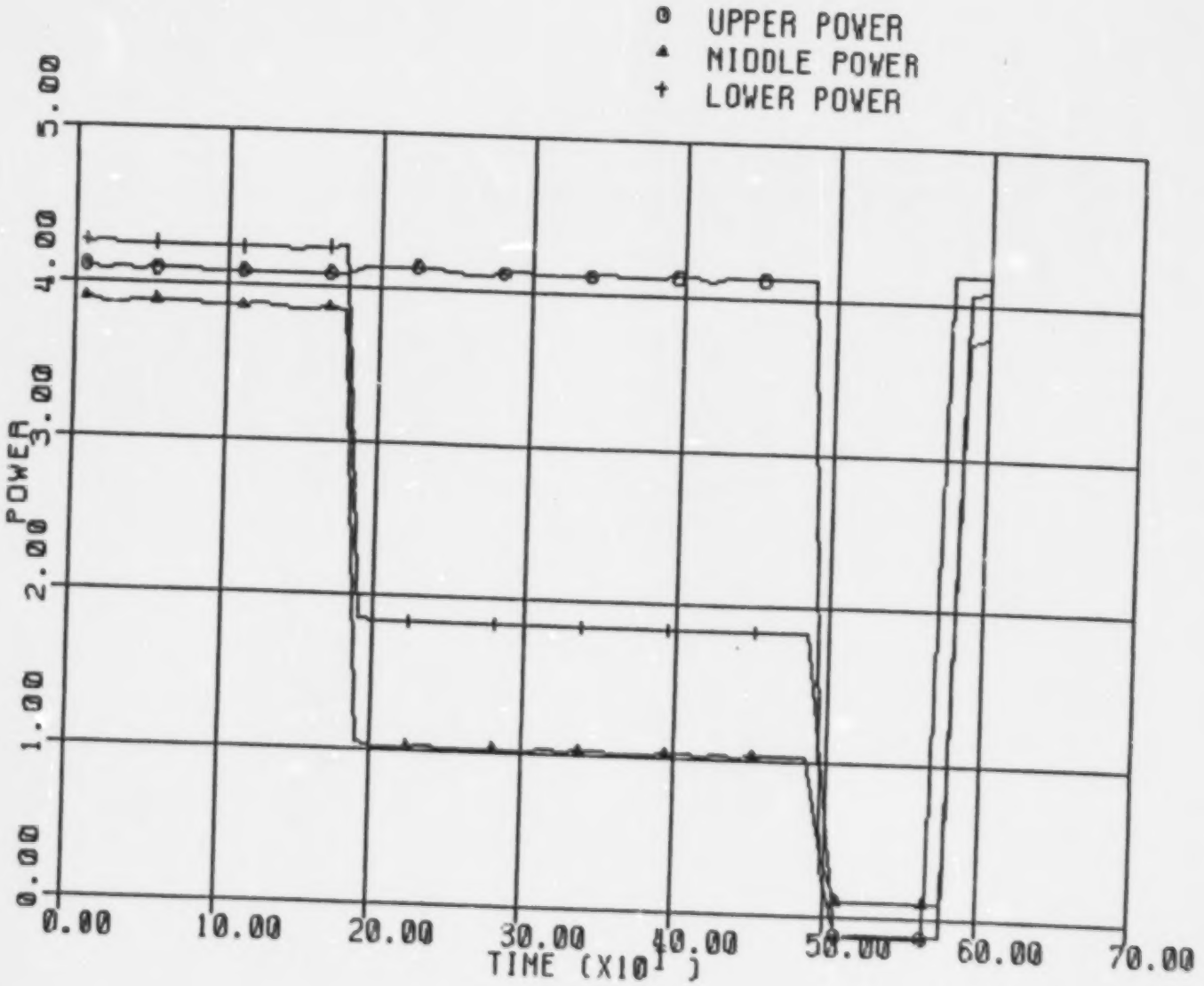


FIGURE 4.2.2-6

AUG30016

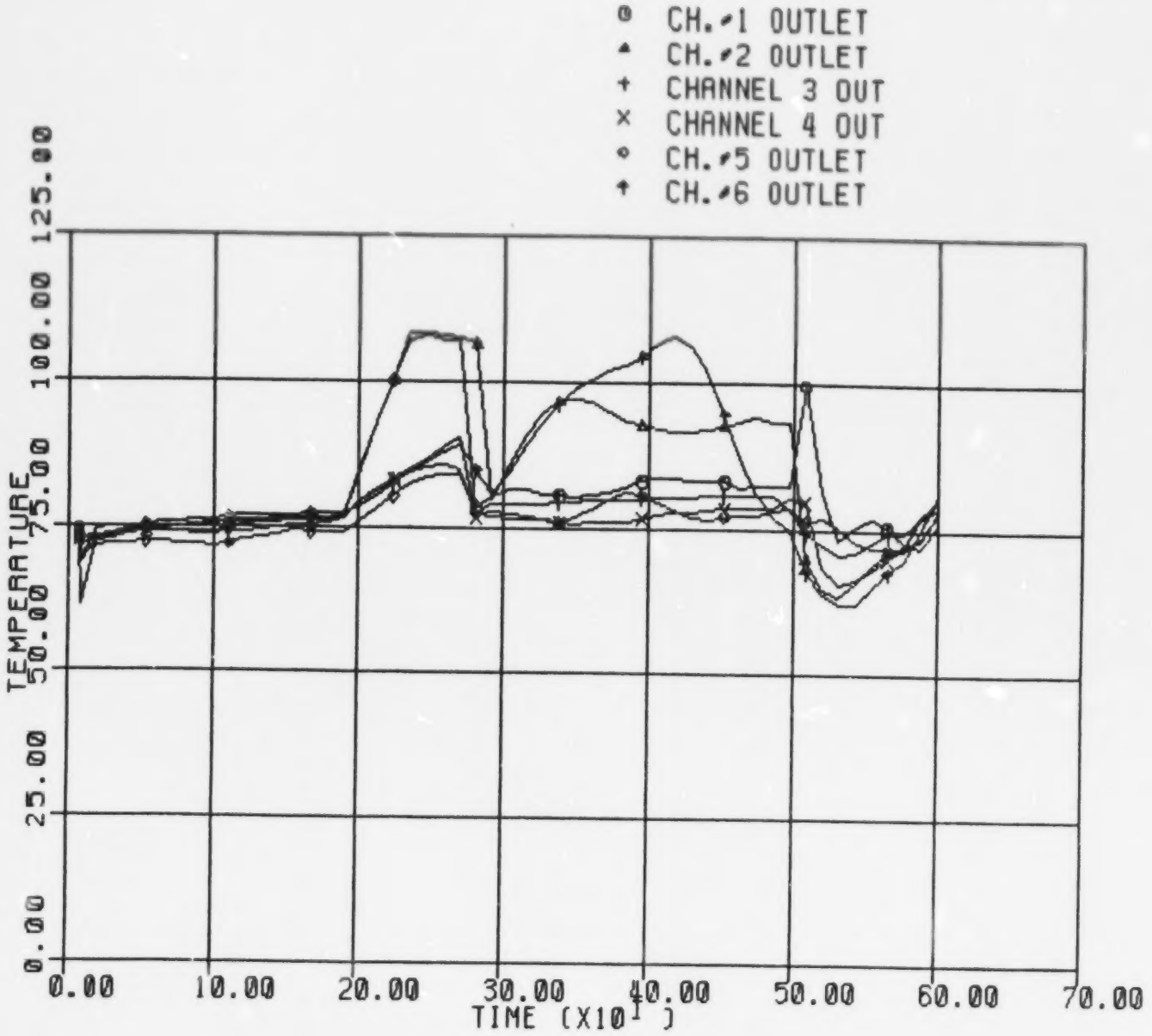


FIGURE 4.2.2-7

AUG30016

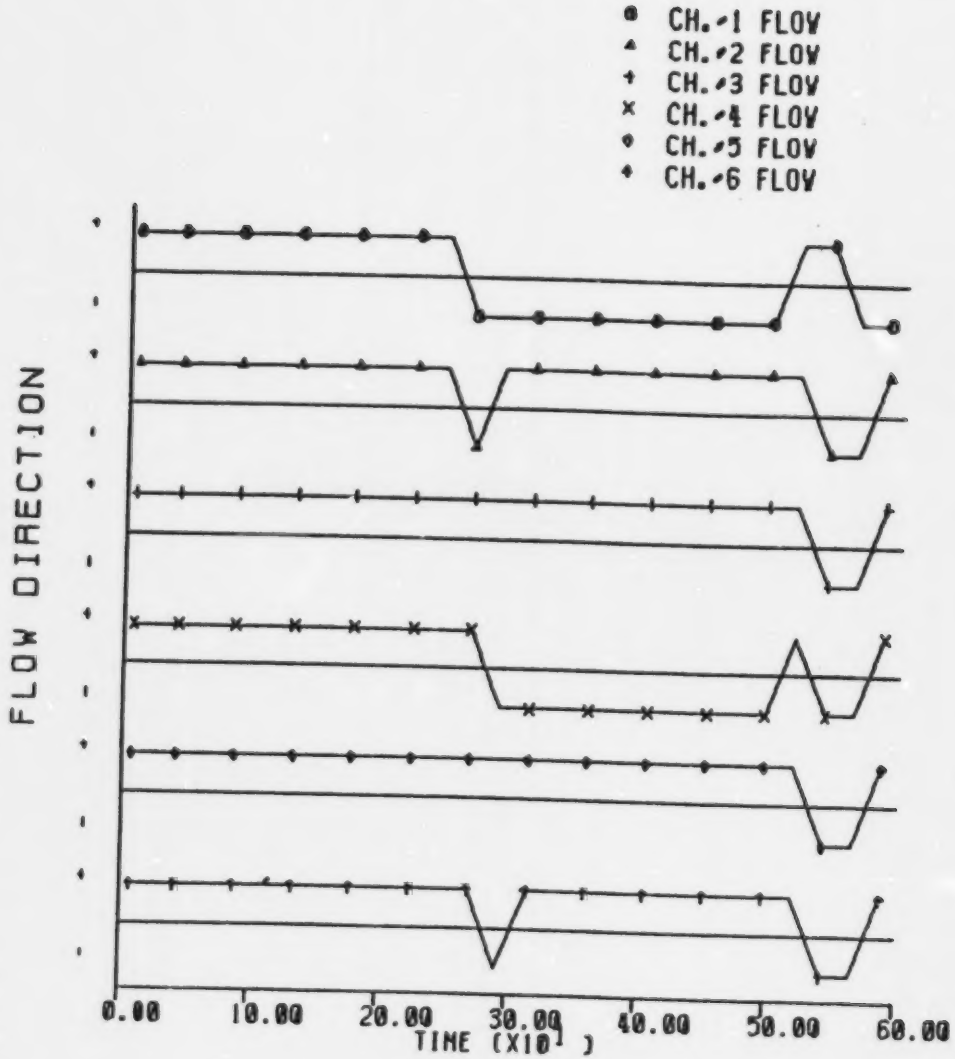


FIGURE 4.2.2-8

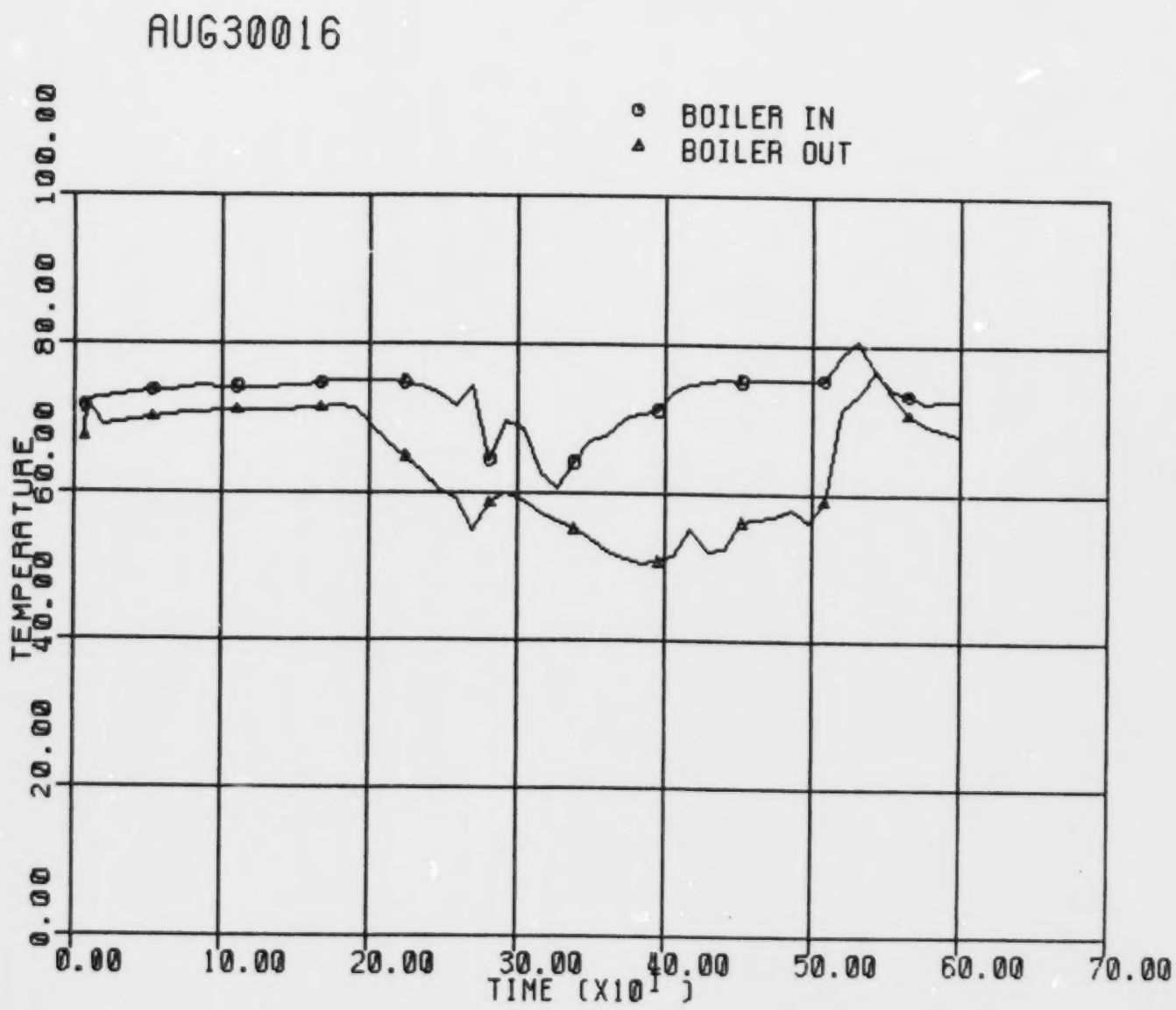

AUG30016
BOILER IN
BOILER OUT
TEMPERATURE
0.00
20.00
40.00
60.00
80.00
100.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
TIME (X10)

FIGURE 4.2.2-9

AUG30016

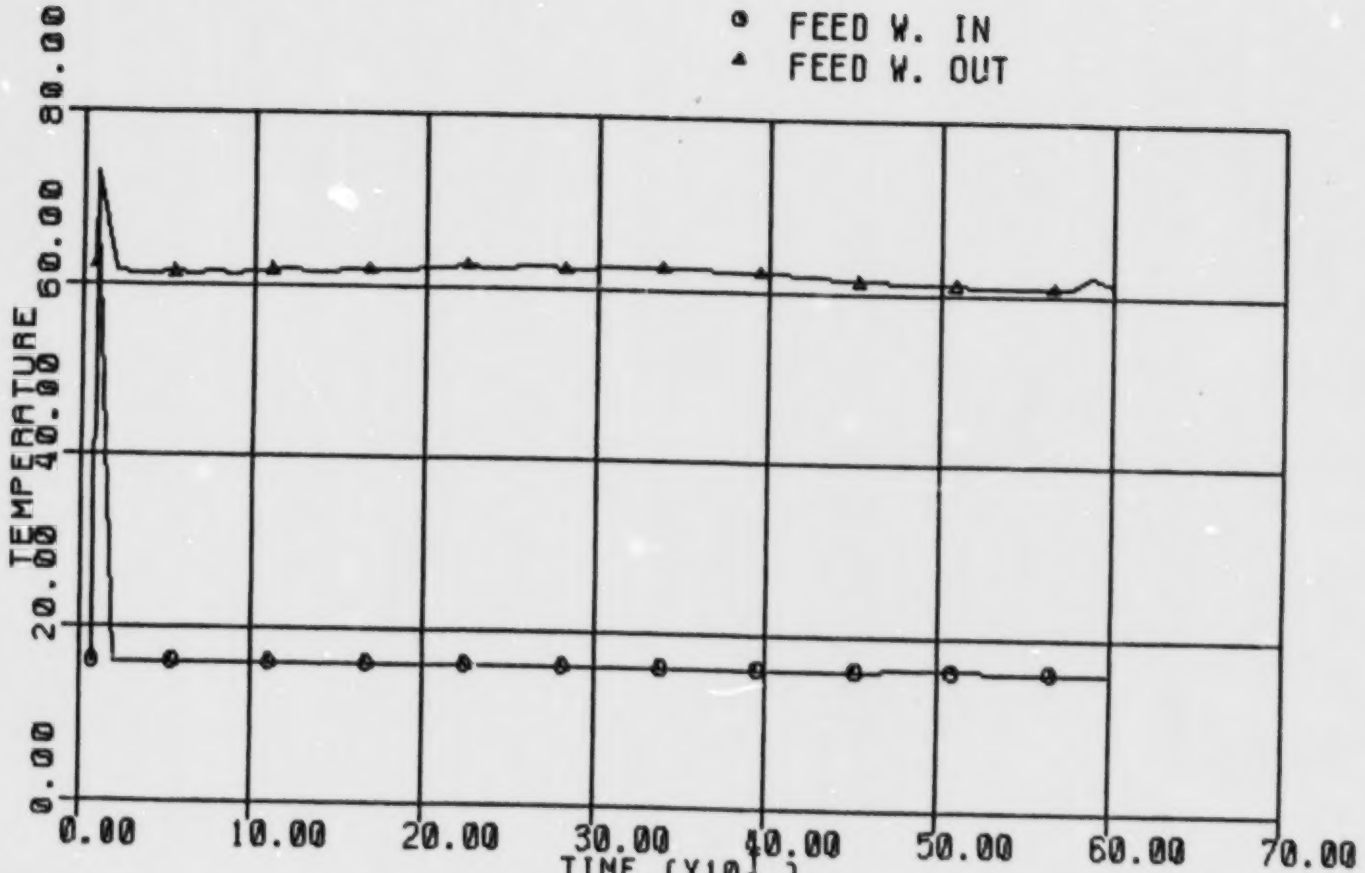


FIGURE 4.2.2-10

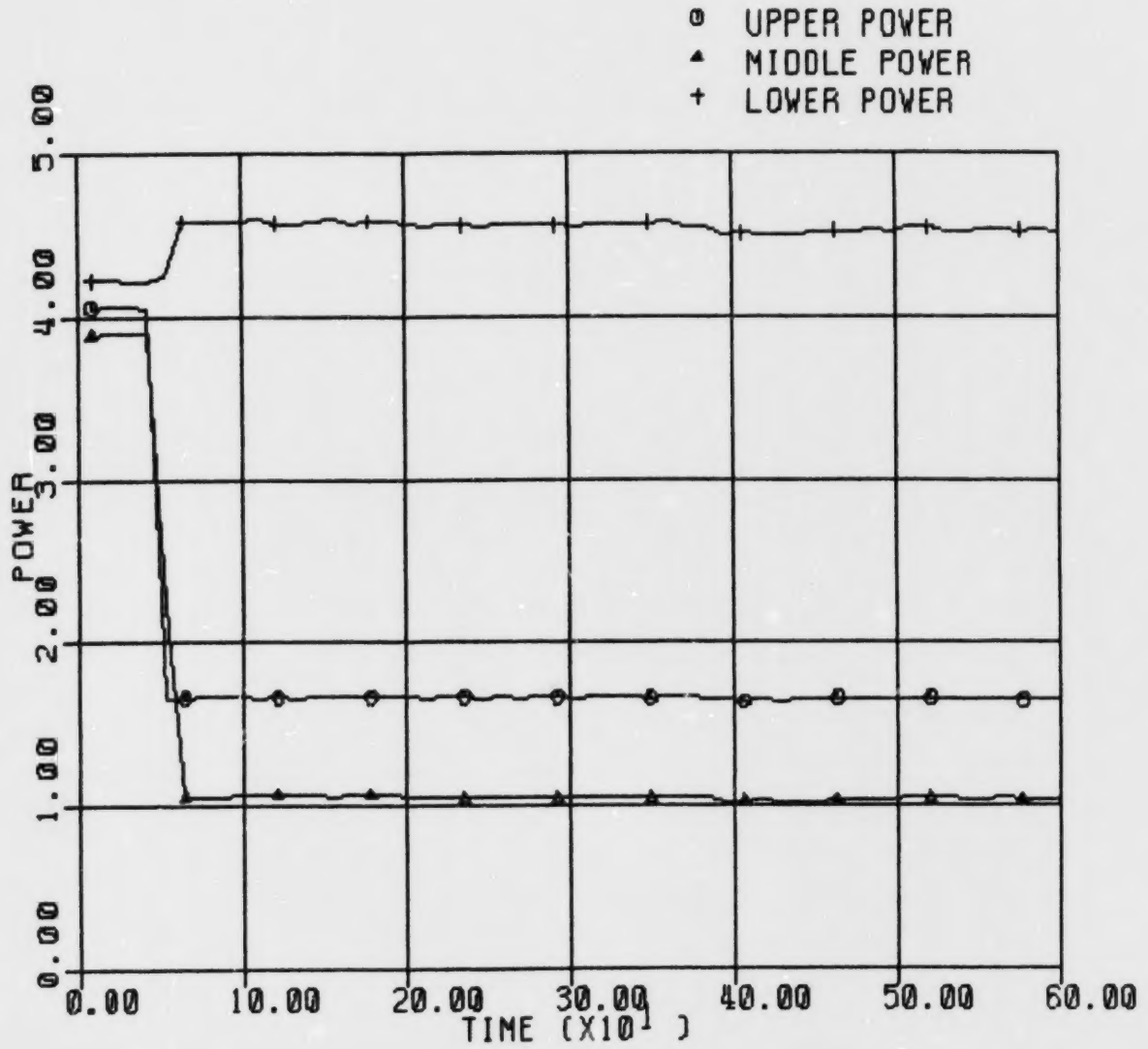


FIGURE 4.2.2-11

AUG30011

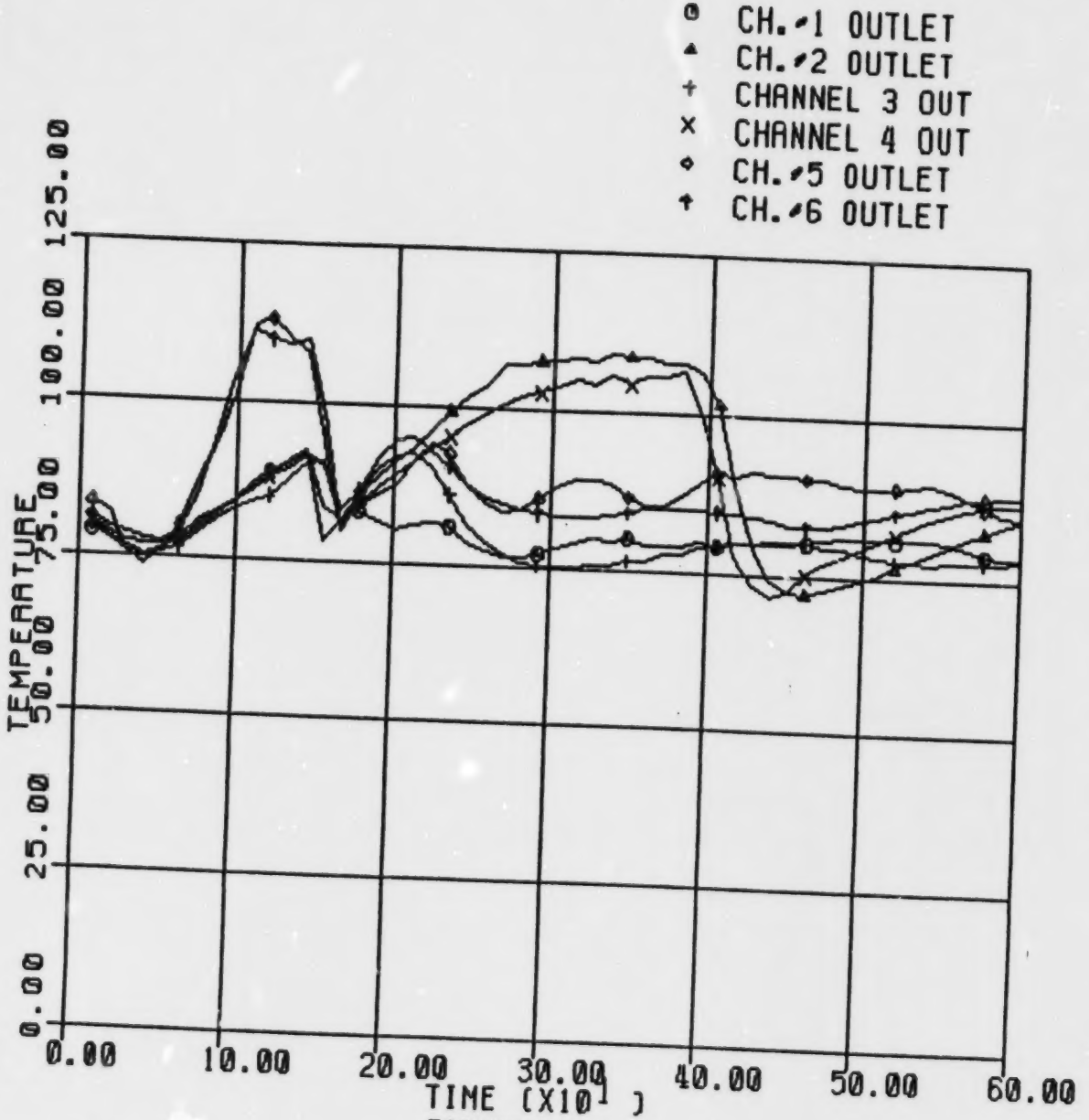


FIGURE 4.2.2-12

AUG30011

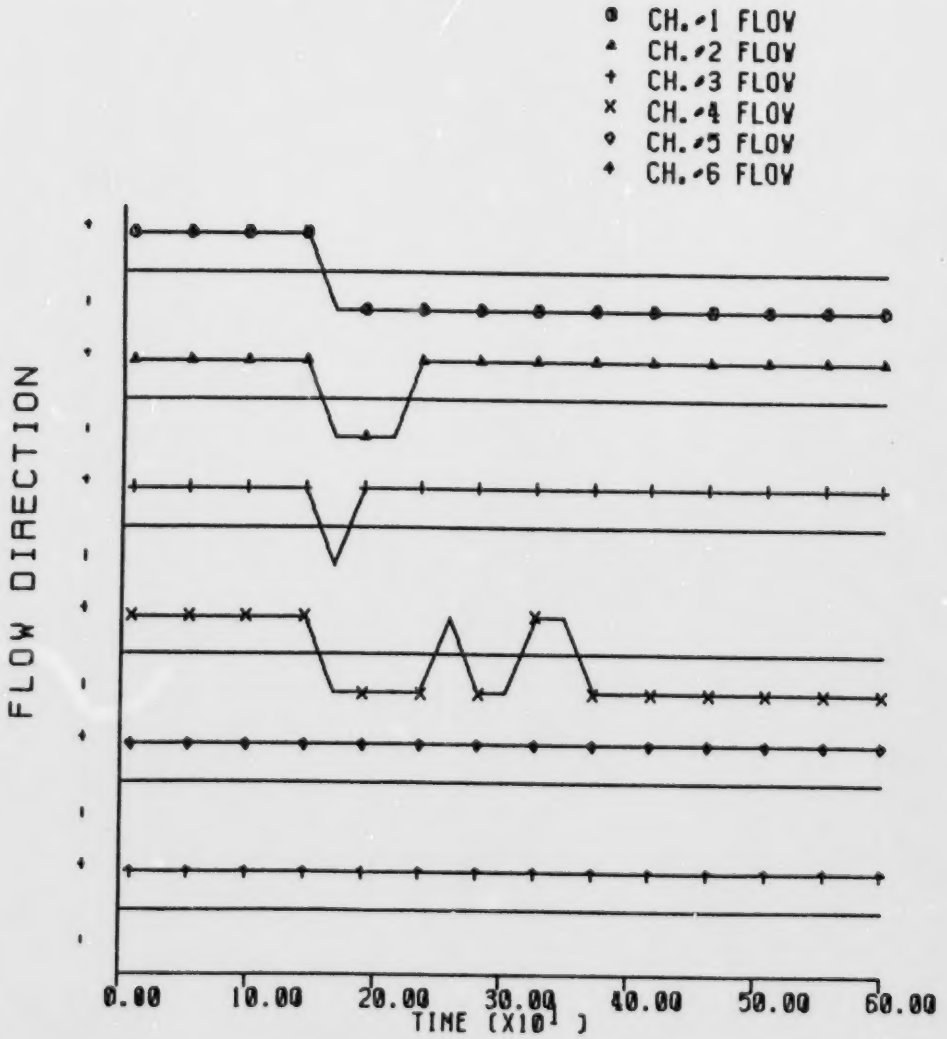


FIGURE 4.2.2-13

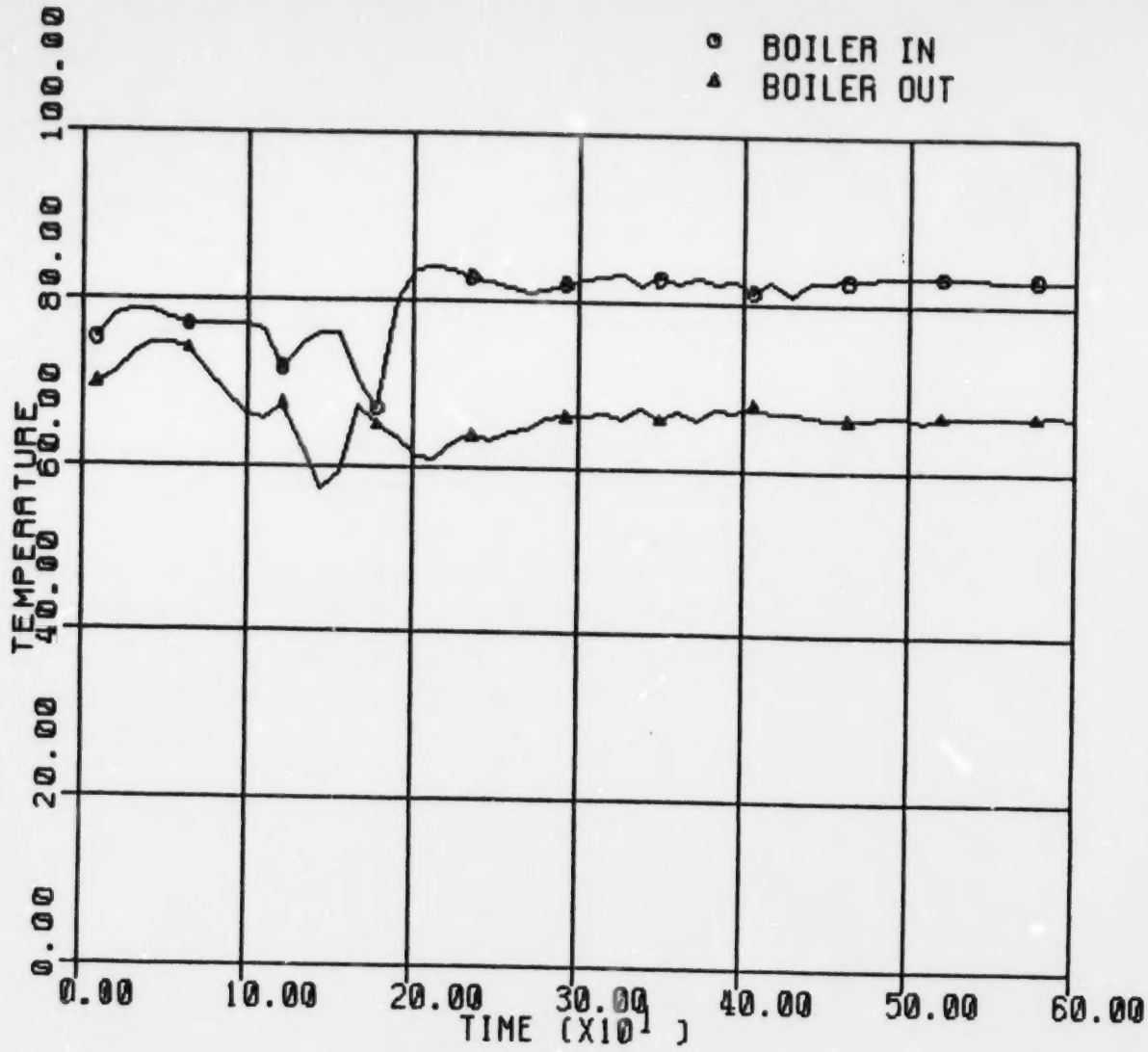


FIGURE 4.2.2-14

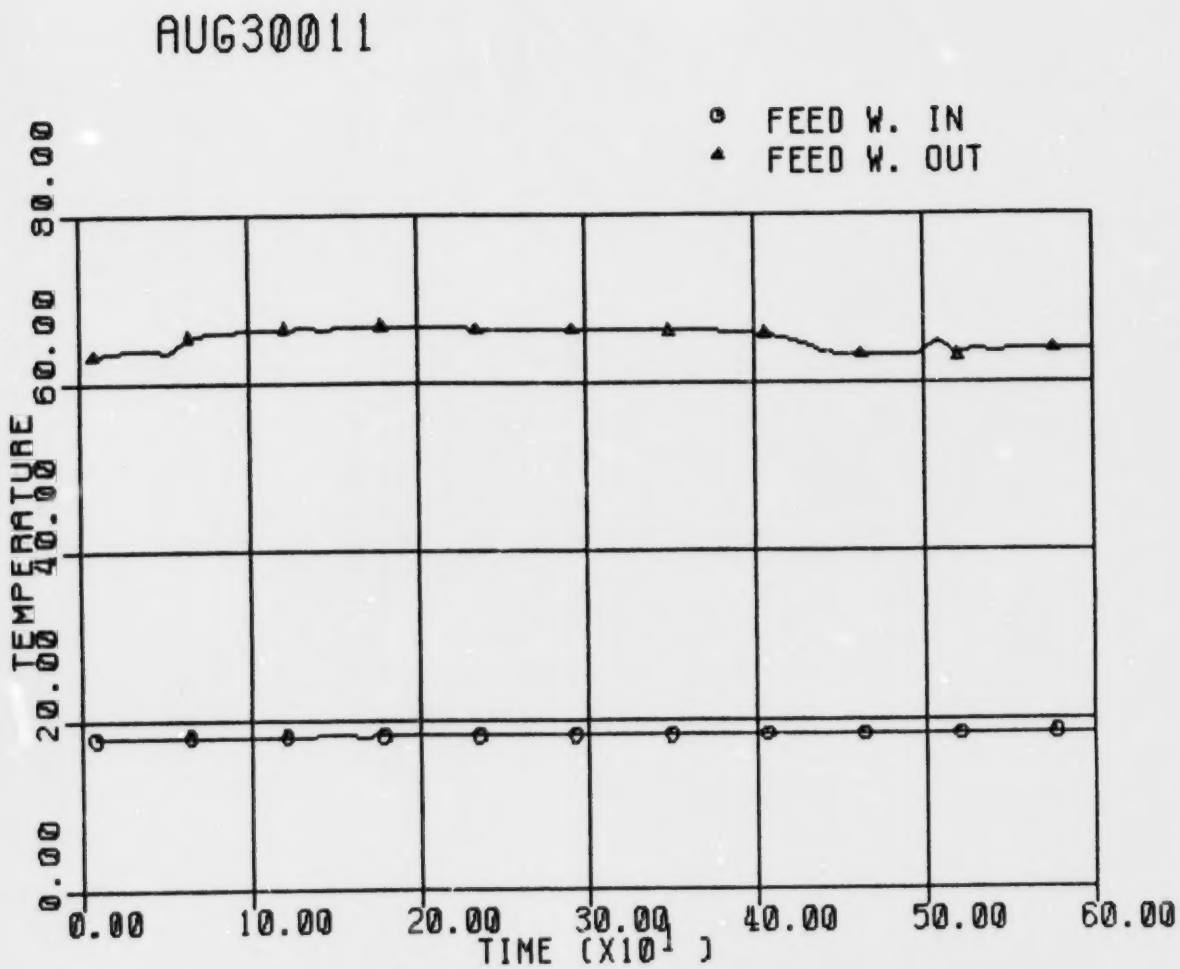


FIGURE 4.2.2-15

SEPT9011

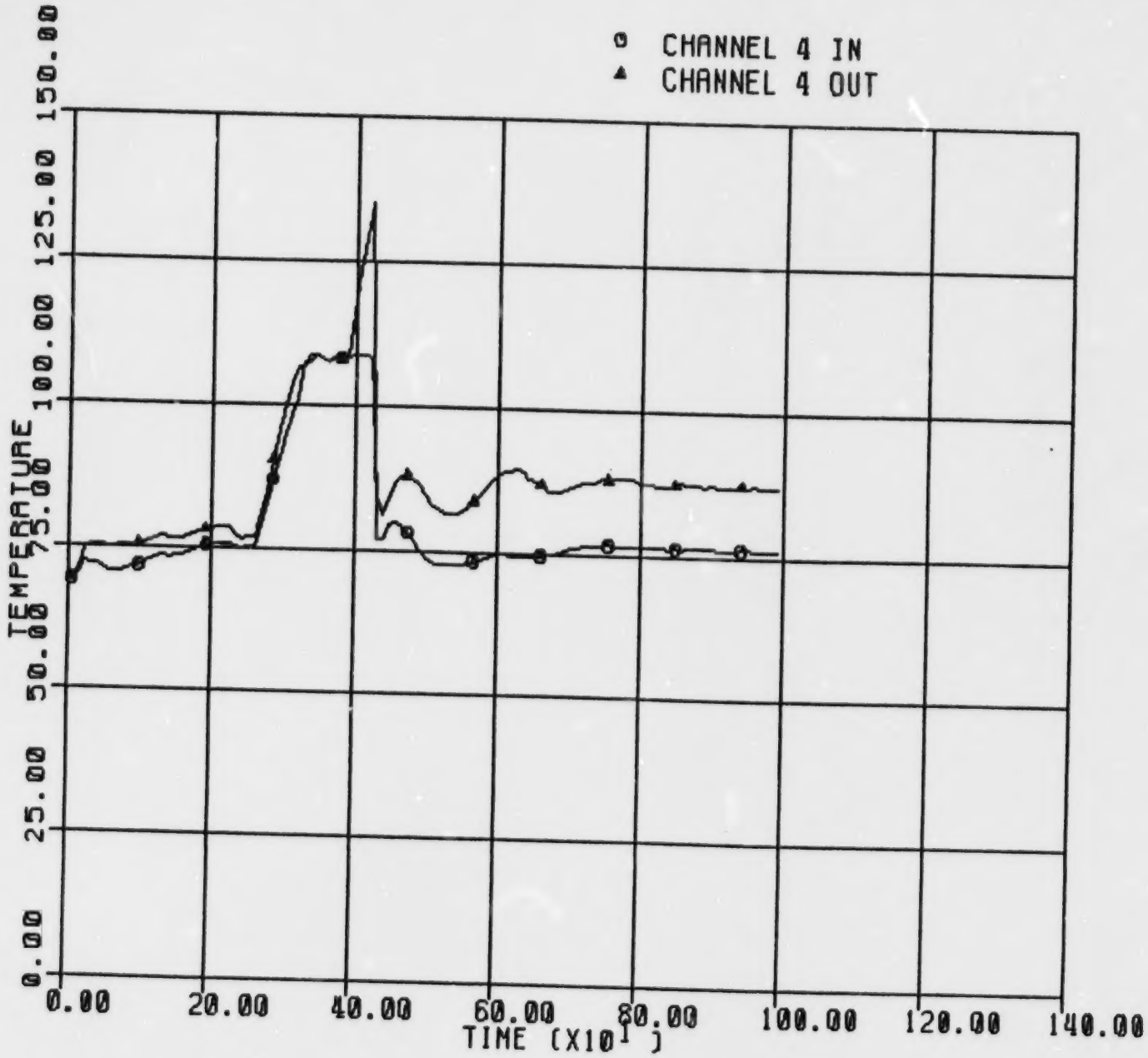


FIGURE 4.2.2-16

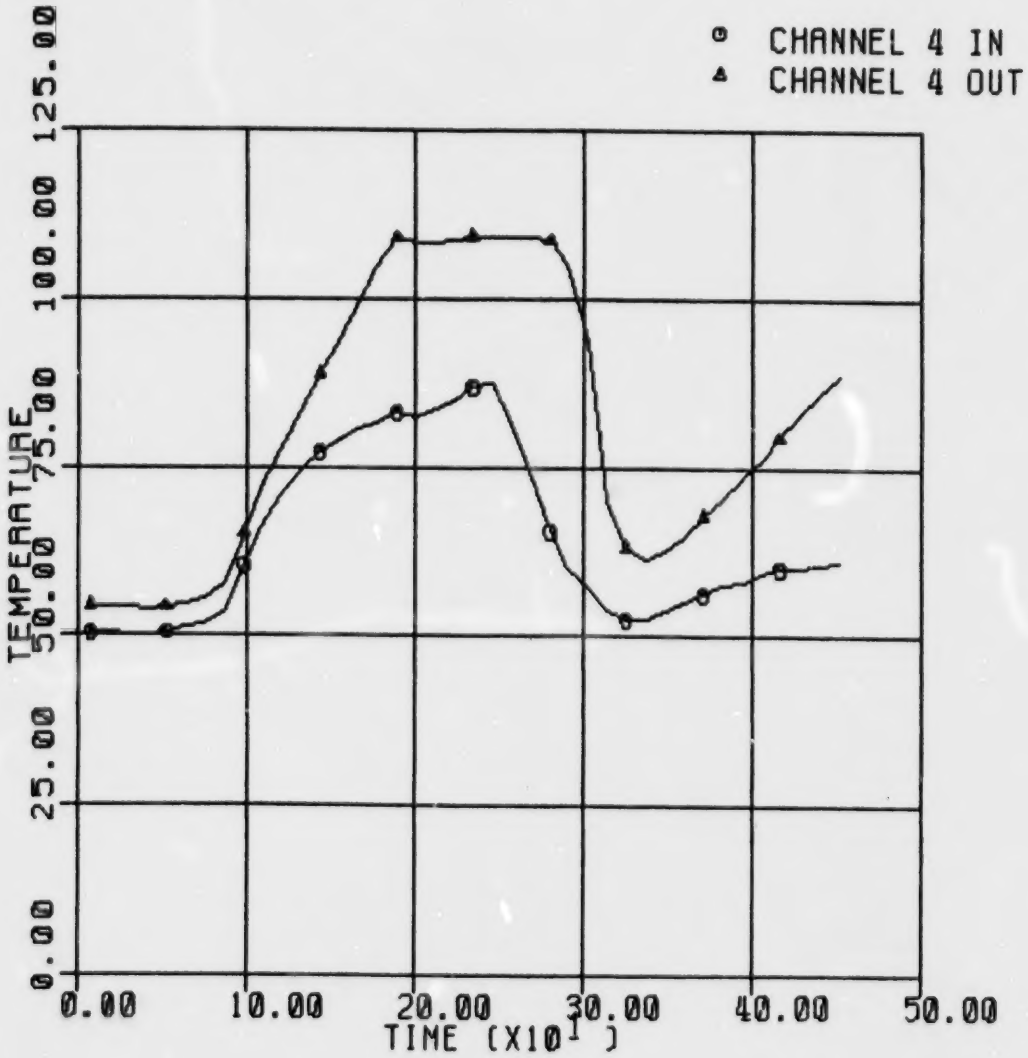


FIGURE 4.2.2-17

The effect of test scenario on the behaviour of channel 4 was tested. Standing start tests with the middle channels at higher power caused stagnation in channel 4. A pump trip test with high power in the middle and lower channels also led to stagnation in channel 4.

4.2.2.1 Effect of Header Size

After the August 31 tests, the extensions in the headers were removed and some pump trip tests were repeated. No differences in system behaviour could be identifed during testing with the shorter headers.

4.2.2.2 Two Channel/Pass Pump Trip

The pump trip tests were repeated with channels 5 and 6 removed from the system. The inlet and outlet feeders for the channels were disconnected from the headers and the header connection pipes were capped. Figures 4.2.2.2-1 to 4.2.2.2-5 show the outcome of a two channel/pass pump trip test with power controls set at 0.8. After the pump was tripped at 280 s, the heated channels boiled, however some forward flow was maintained. Channel 4 was the last to re-fill in the four channel tests, however it did re-fill in all tests before heater temperature rose above saturation. In the test described here all flows were in the forward direction at the termination of the test. For some cases, flow reversal took place in two channels of opposite core passes. A typical flow pattern would be reverse flow in channels 1 and 4 and forward flow in channels 2 and 3. These patterns were also seen earlier in the project and are fully described in volume 1 of this report. With two channels per pass, flow reversal in two channels results in very little flow through the boilers. The forward flowing channels feed the reverse flowing channels, and the only flow in the boilers is the small forward/reverse differential. The whole system below the boilers then heats up once the boilers have been effectively

SEP10007

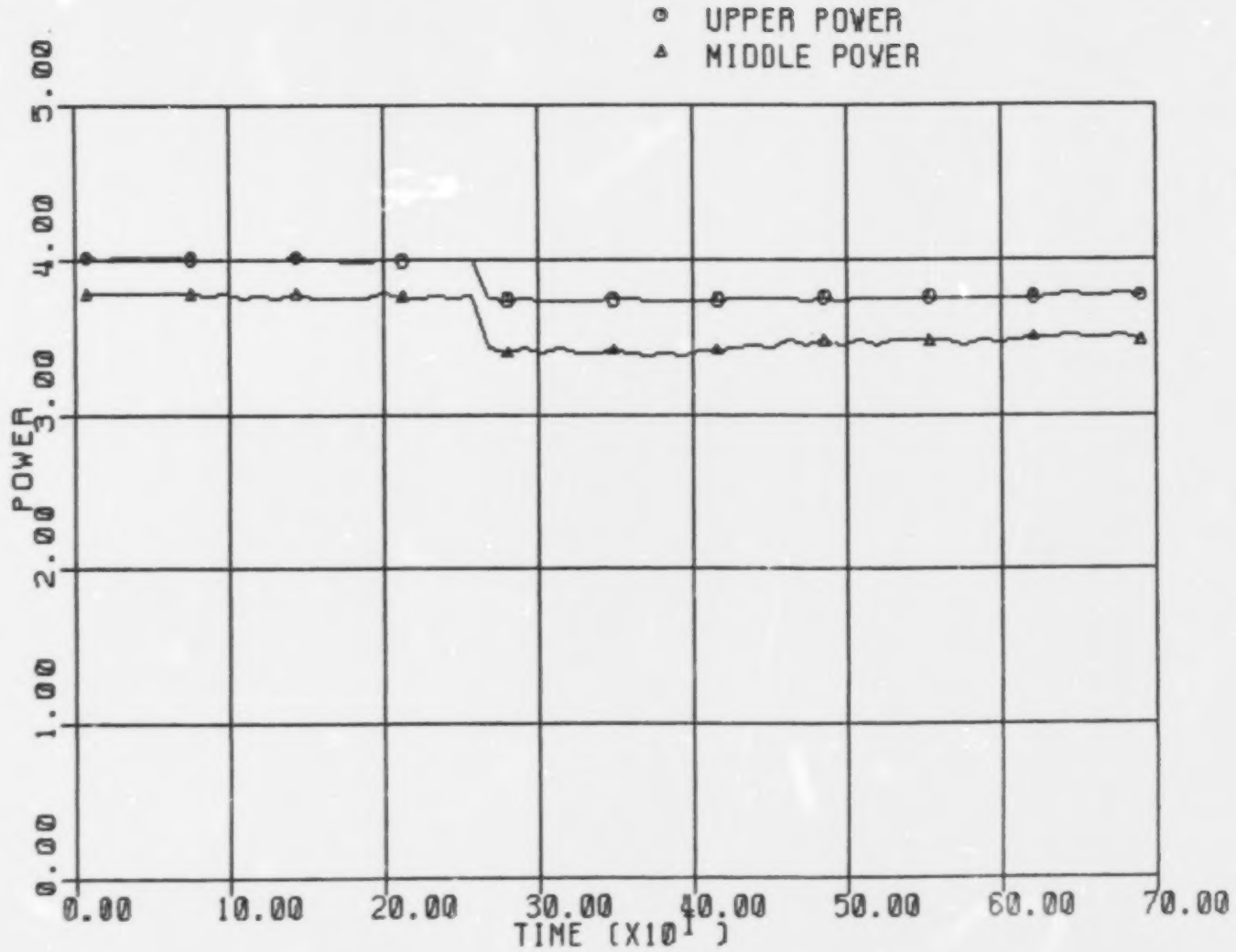


FIGURE 4.2.2.2-1

SEP10007

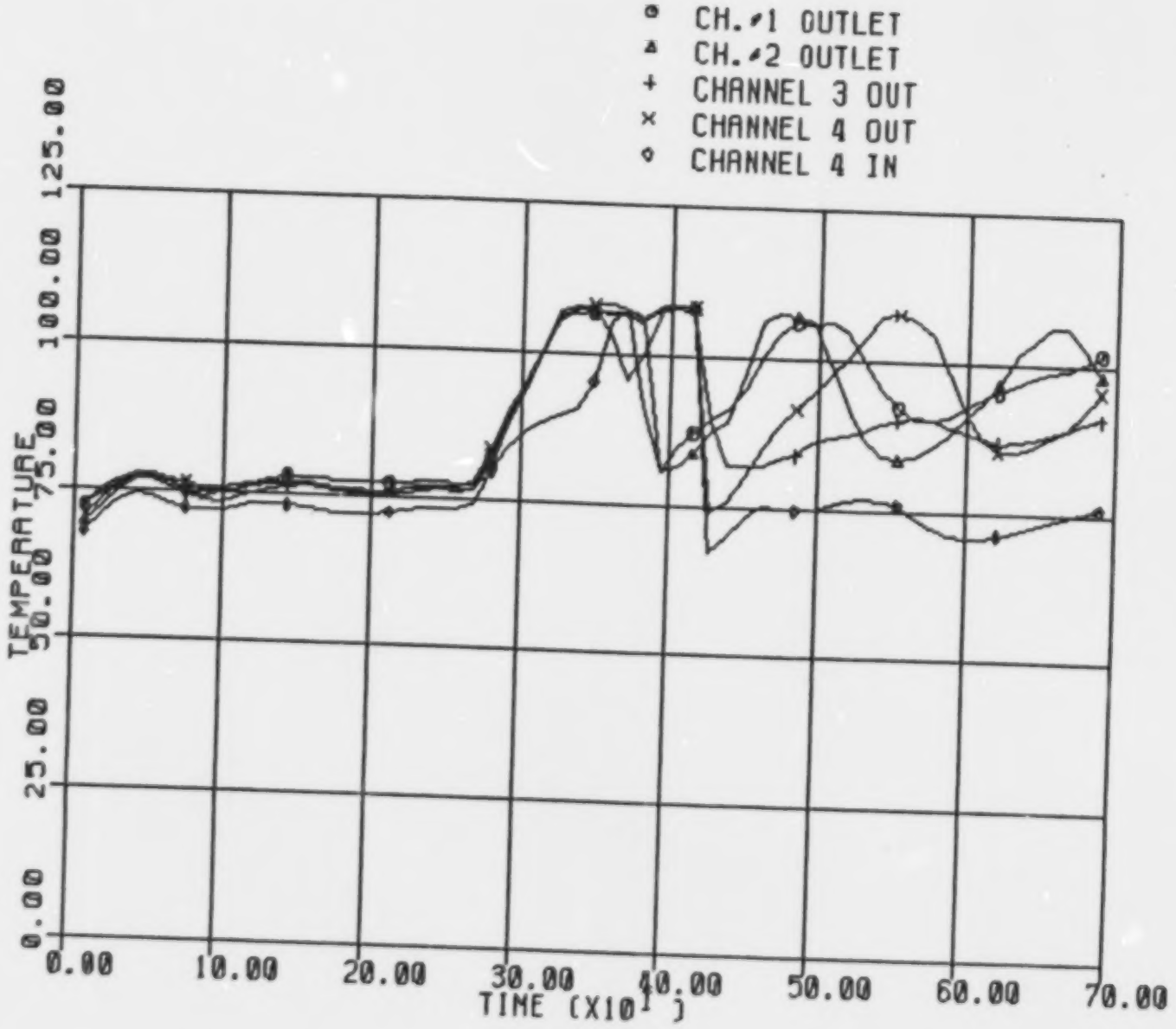


FIGURE 4.2.2.2-2

SEP10007

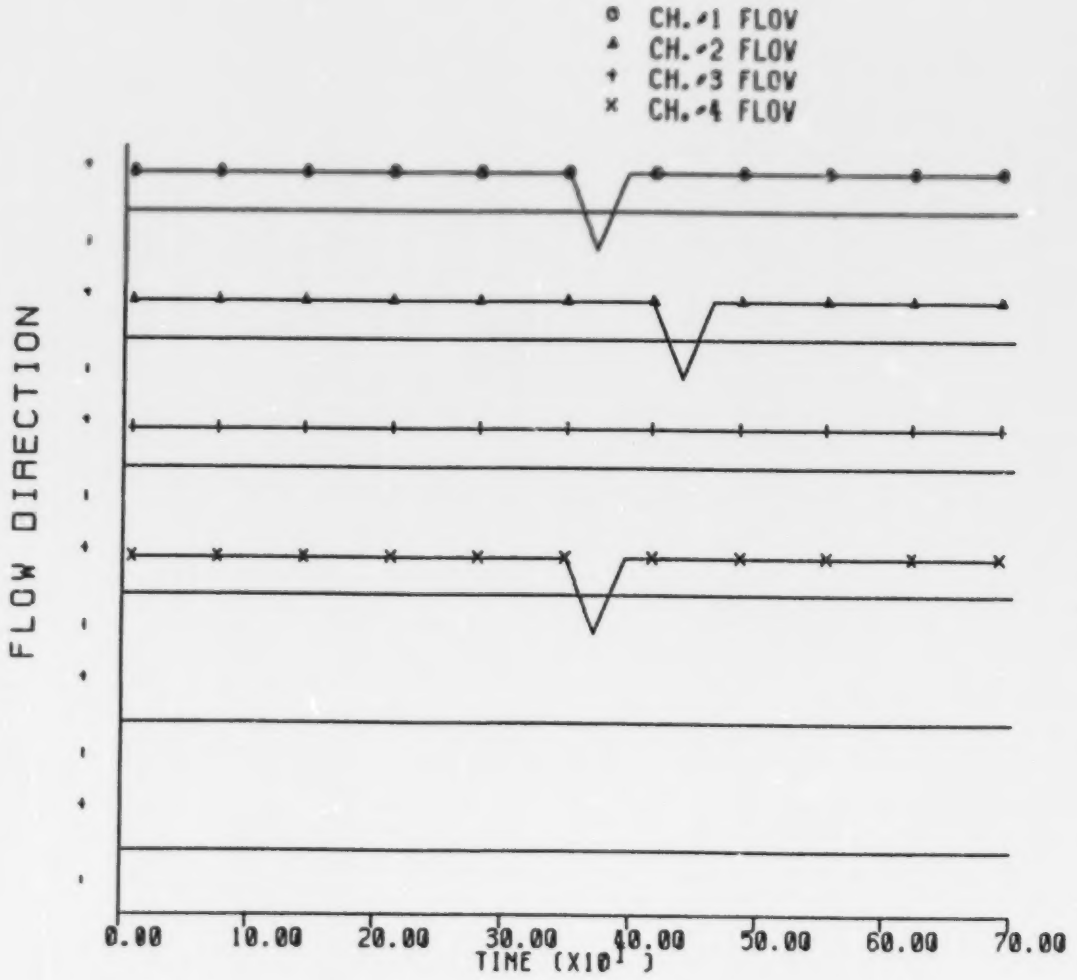


FIGURE 4.2.2.2-3

SEP10007

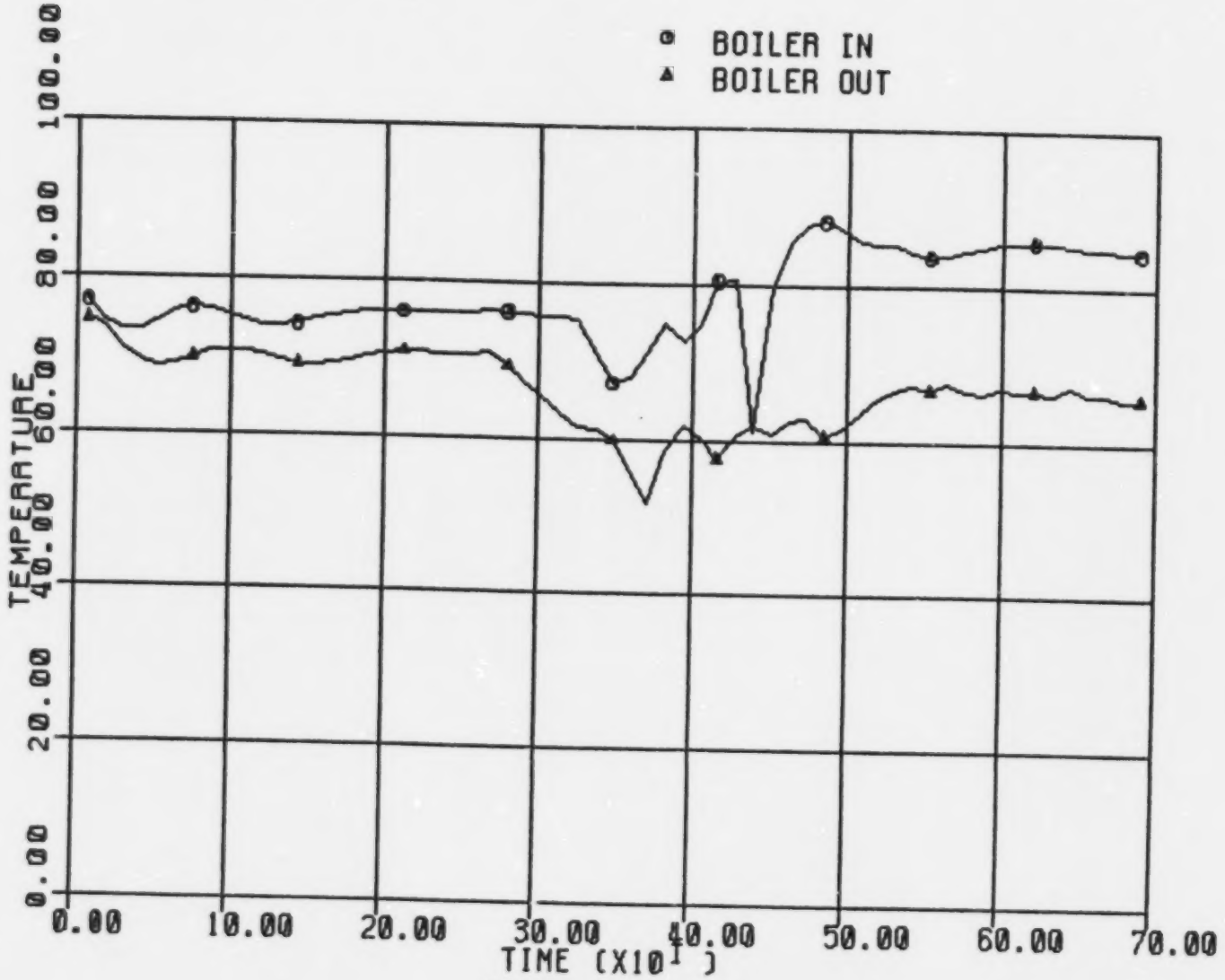


FIGURE 4.2.2.2-4

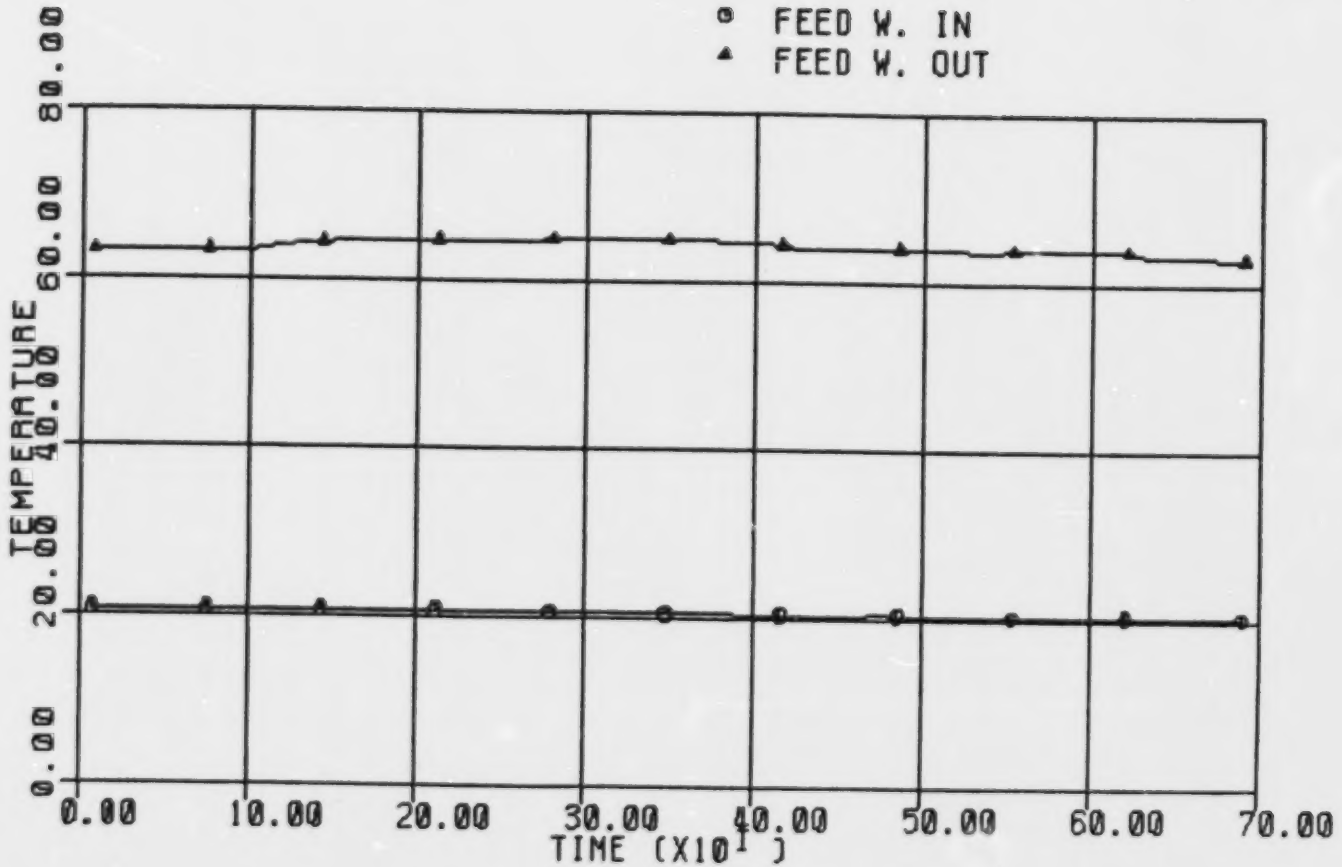


FIGURE 4.2 2.2-5

removed as a heat sink. This is different from the three channel per pass case where flow reversal can occur while still maintaining heat removal capability in the boilers.

4.3 Other Tests

4.3.1 Pump Operation During Reverse Flow

This experiment was done during a slow power ramp test. During the power ramp, the channels went through a period of boiling and the final flow pattern had channels one and six with reverse flow and forward flow in the other channels. Figure 4.3.1-1 shows the flow pattern during the test. The pumps were started at 3000 s, and pump speed was slowly increased in an attempt to stop the reverse flow in channels 1 and 6. As pump speed and head increased, the flows in channels 1 and 6 decreased until boiling began, and eventually the flows were driven forward. Figure 4.3.1-2 shows temperatures. Pump speed could not be manipulated to hold a stagnation condition in the channels. After the pumps were shut off, flow in channels 1 and 6 reversed again.

4.3.2 Crash Cooldown With Reverse Flow

Figures 4.3.2-1 to 4.3.2-5 show results from a test where reverse single phase thermosyphoning was established and then the boilers were crash cooled. The pumps were run backwards initially to establish the reverse flow. At 1850 s, reverse thermosyphoning was established, and crash cooldown was initiated at 2300 s. As shown in figure 4.3.2-2, system temperature drops due to the crash cooldown and flow remains single phase in the reverse direction (figure 4.3.2-3). Thus, the injection of cold water into the hot leg of the boiler does not break down thermosyphoning flow or cause flow reversal.

SEP06001

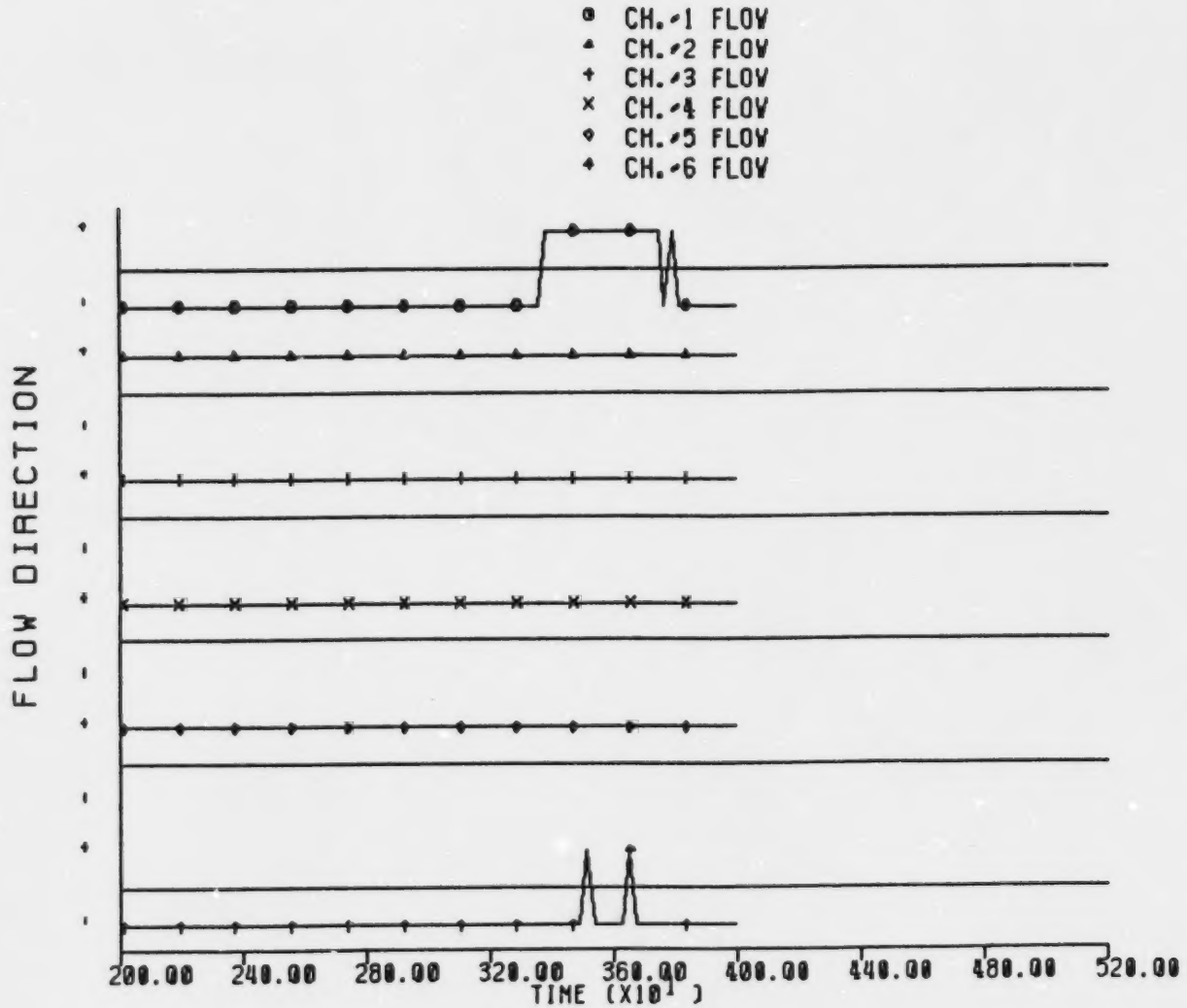


FIGURE 4.3.1-1

SEP06001

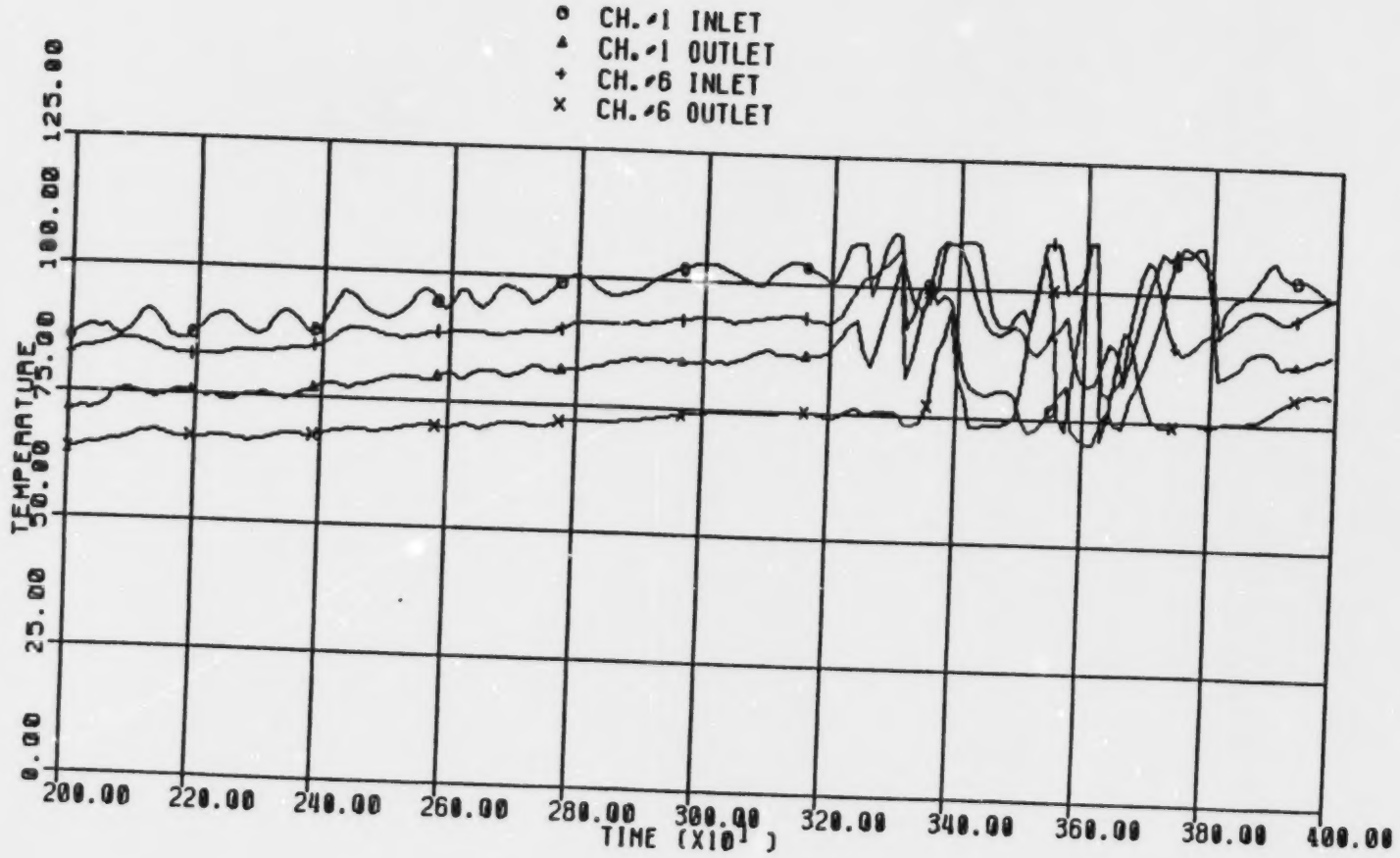


FIGURE 4.3.1-2

SEP17002

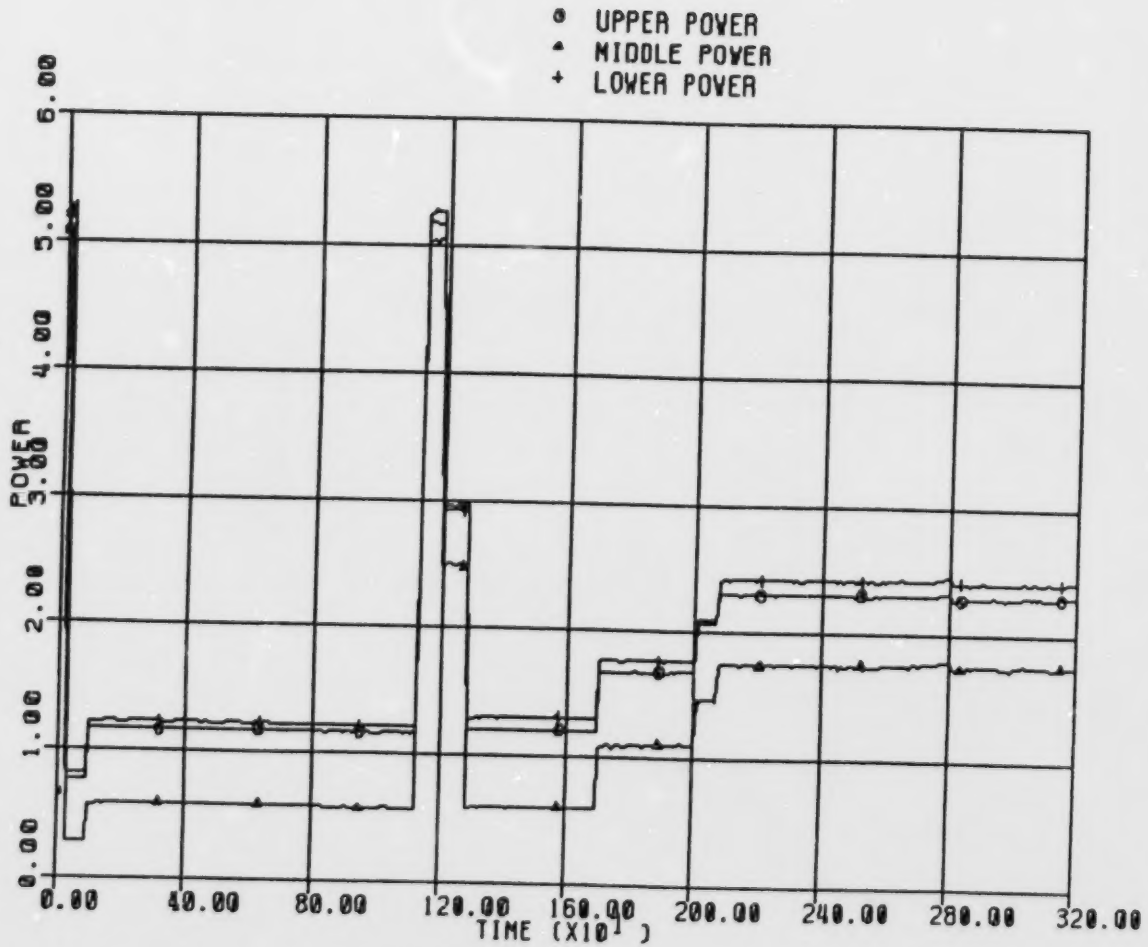


FIGURE 4.3.2-1

SEP17002

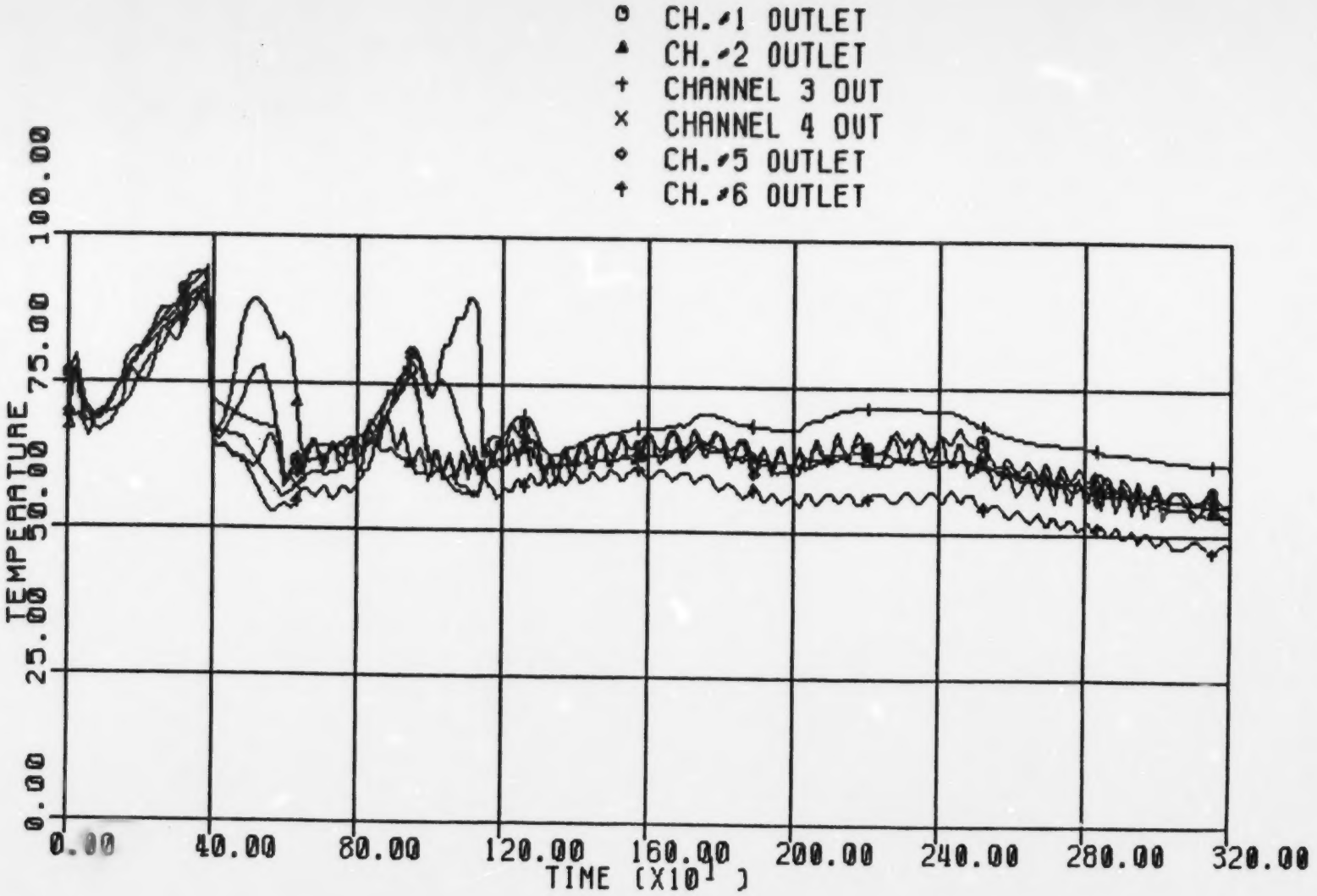


FIGURE 4.3.2-2

SEP17002

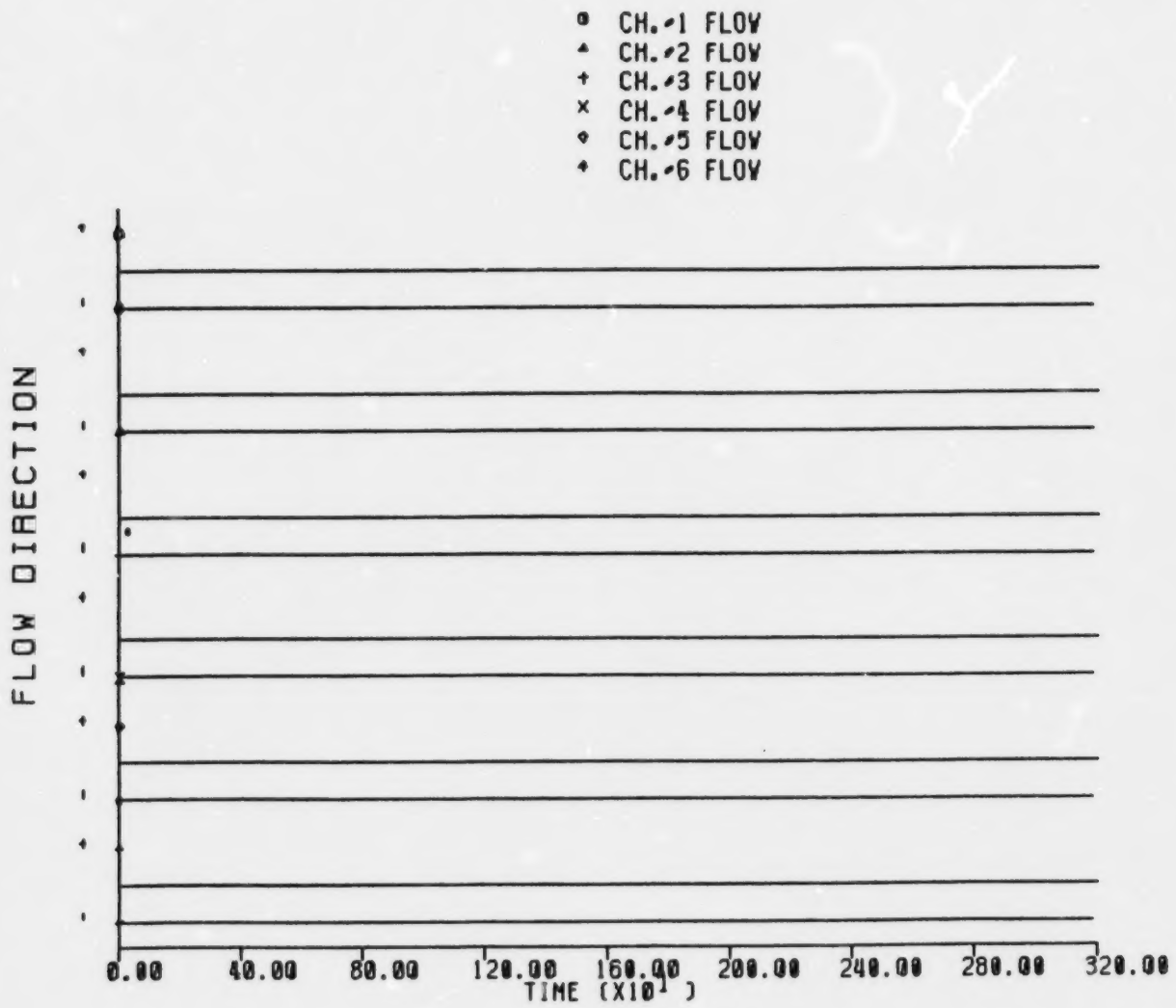


FIGURE 4.3.2-3

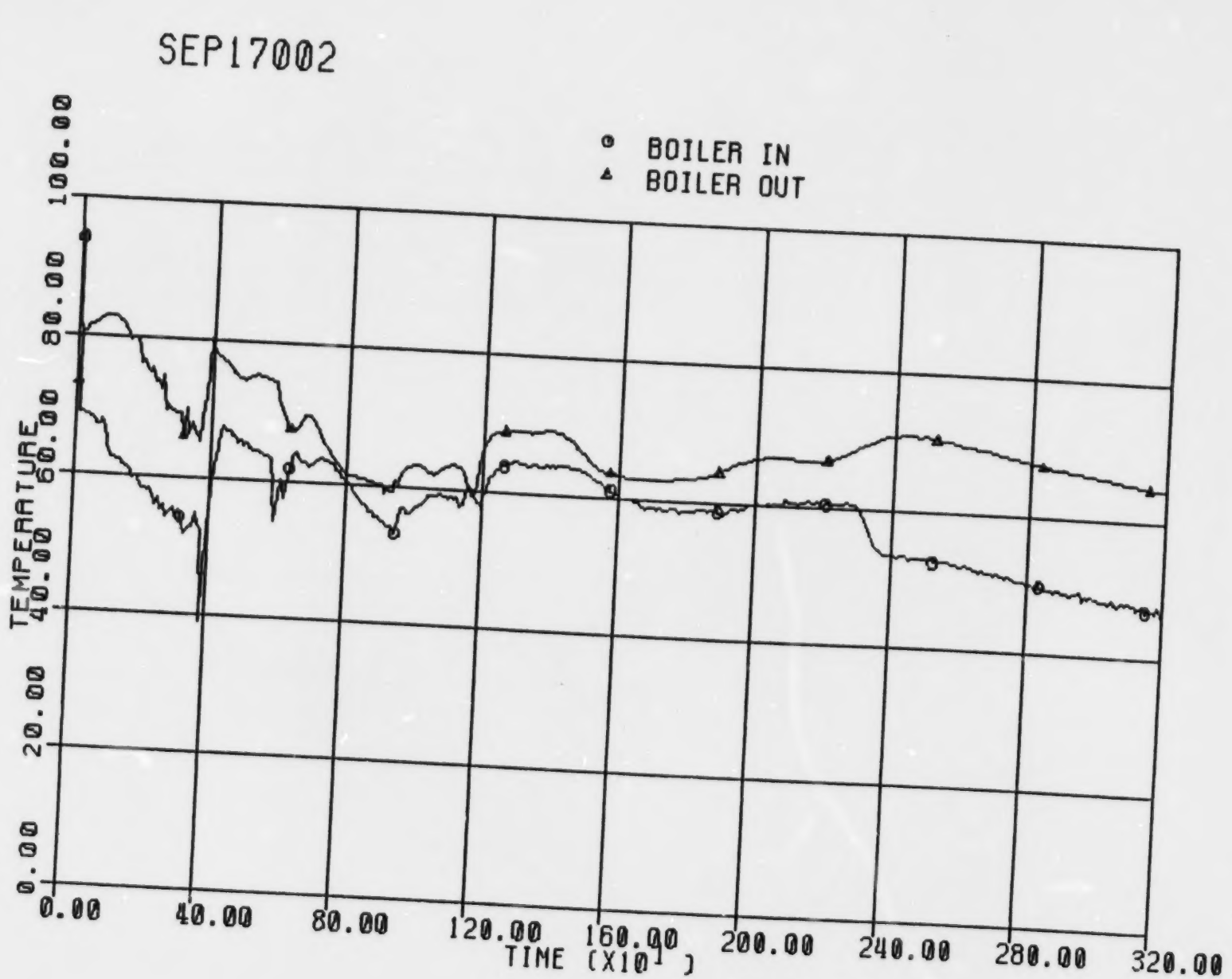

SEP17002
BOILER IN
BOILER OUT
TEMPERATURE
0.00
20.00
40.00
60.00
80.00
100.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
TIME (X10)

FIGURE 4.3.2-4

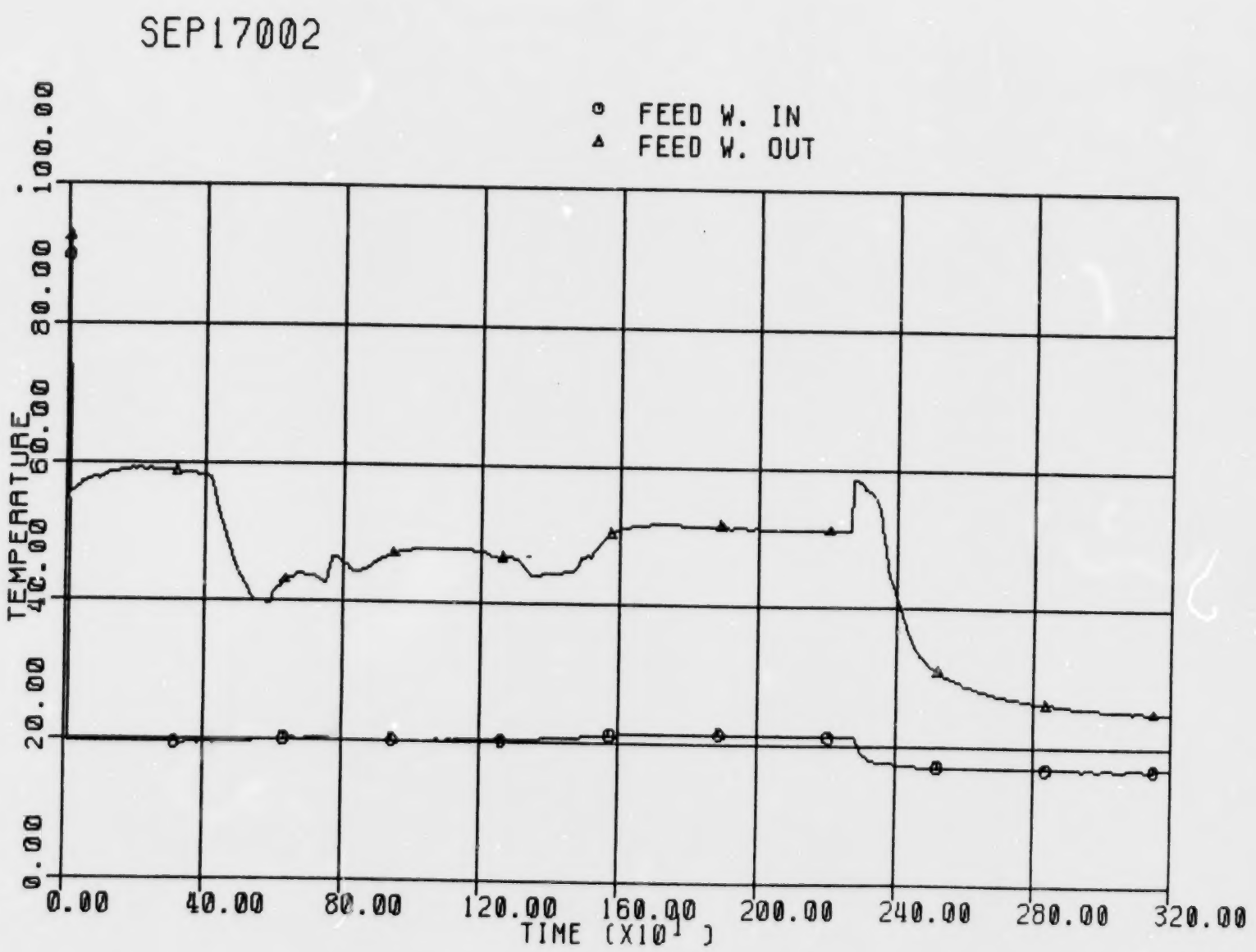

SEP17002
FEED W. IN
FEED W. OUT
TEMPERATURE
0.00
20.00
40.00
60.00
80.00
100.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
TIME (X10¹)

FIGURE 4.3.2-5

5.0 VIDEOTAPING

Seven tests were recorded on videotape. Two video recorders were used: one focused on the rig and the other on the VT100 used to monitor the experiments in progress. Two VHS players with monitors are required to view the videotapes. Sound is dubbed on the rig videotape to explain each test as it is viewed.

The first four tests on the videotape show pump trip cases with the rig set up with three channels per pass. A crash cooldown with reverse flow in two channels is shown in one of the tests.

The last three tests show rig operation with two channels per pass. Three pump trip tests and a standing start test are shown.

6.0 ADDITIONAL TESTING WITH LONG FEEDERS

After the tests described above were completed, it was decided to increase the length of the horizontal sections of the two center channels, to simulate more closely some of the long horizontal runs in an actual reactor. Details of the results obtained are given in Appendix C.

During the modifications to the rig, it was found that due to assembly error and/or possible channel movement, that at Channel 4 outlet 'T', the two horizontal sections of the pipe were nearly touching. This increased resistance probably accounted for the high temperatures measured in Channel 4 that were observed previously (see paragraph 4.2.2). After the resistance was reduced, similar high temperatures could not be duplicated.

7.0 CONCLUSIONS

The tests done with the rig modified for three channels per pass show behaviour which could not be seen with the two channel per pass configuration. Flow reversals can occur in the larger rig without fully bypassing the boilers as a heated sink. This cannot happen in the smaller rig. The periods of stagnation seen in channel 4 were longer with six channels than with four. From the results obtained here it was difficult to conclude that the larger number of channels caused longer stagnations, however, this possibility was not ruled out. From the observations presented here it can be concluded that more than two heated channels per pass are required to study natural circulation using a test rig.

Correct simulations of channel and end fitting flow resistance is extremely important if coolant stagnation is being studied.

The temperature instrumentation provided the most useful information and should be included in any natural circulation test rig.

Sensitive turbine flow meters do not seem capable of providing useful measurments of the low thermosyphoning flows, (see Appendix A).

APPENDIX A

DESCRIPTION OF TURBINE FLOW METER

Description of Turbine Flow Meter

The turbine flow meter was installed to determine the usefulness of the instrument for measuring thermosyphoning flows and for indicating sudden changes in flow (due to channel flushing) in the test rig. The flow meter was calibrated by pouring through a measured quantity of fluid and counting pulses. Several calibration tests gave a flow meter calibration factor of .022 ℓ/pulse. The HP85A controller was programmed to count pulses from the turbine flow meter during the interval required for acquisition of all the rig data during each sampling period. The volumetric flow was determined using the number of counts, the time interval, and the calibration factor:

$$Q = \frac{.022 \times N}{I}$$

where Q = flow (liters/s)

N = number of counts

I = counting interval (s)

Figure A-1 shows the flows measured by the turbine flow meter in the channel 4 outlet feeder during a pump trip test. The low channel flows during single phase thermosyphoning are insufficient to drive the flow meter, however, when a channel flushes flow is large enough to register on the instrumentation. The "spikes" in figure A-1 indicate feeder flow when the channel flushes averaged over the 8 s sampling period.

SEP19006

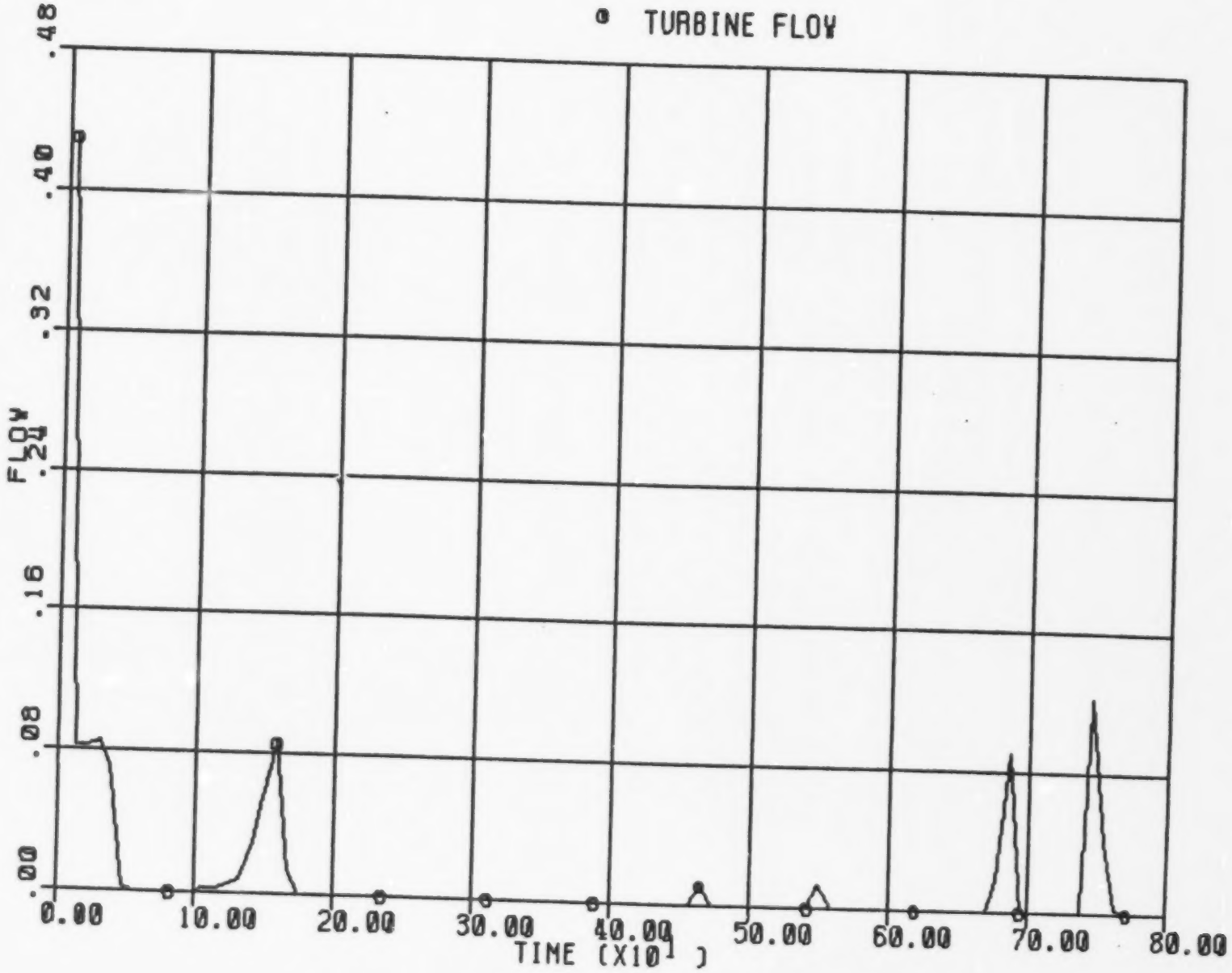


FIGURE A-1

APPENDIX B

SUMMARY OF TESTS CONDUCTED WITH THE FLOW VISUALIZATION RIG

SUMMARY OF TESTS CONDUCTED WITH THE FLOW VISUALIZATION RIG

This appendix is a list of the tests done with the flow visualization rig with three heated channels per pass. The tests are listed according to the date of the test and the test number. For example, test AUG23001 was the first test done on August 23.

TEST	DESCRIPTION OF TEST
AUG23001	- Determine required channel power distribution to cause boiling in channels 1 & 2 only.
AUG23002	- Same as AUG23001
AUG23003	- Determine required channel power distribution to cause boiling in channels 3 & 4 only.
AUG24001	- Determine required channel power distribution to cause boiling in channels 5 & 6 only.
AUG28001 to 009	- Determine total rig power required to cause channel boiling following a pump trip, and determine flow patterns after the channels go through a period of boiling following pump trip. - Small (3/4 in I.D.) inlet feeders used for these and all subsequent tests
AUG30001	- Pump trip with power controls at 0.7:0.7:0.7 - Boiler Inlet T=74.5°, Outlet T=70°
AUG30002	- Pump trip with power controls at 0.75:0.75:0.75 - Boiler Inlet T=74°, Outlet T=70°
AUG30003	- Determine the effect of channels 3 and 4 boiling on the rest of the system - Pump trip with power controls at 0.5:0.8;0.5
AUG30004	- Pump trip with power controls at 0.5:0.75:0.5 - Boiler Inlet T=75°, Outlet T=71°

TEST	DESCRIPTION OF TEST
AUG30005	- Pump trip with power controls at 0.5:0.7:0.5 - Boiler Inlet T=75°, Outlet T=70°
AUG30006	- Determine the effect of channels 5 & 6 boiling on the rest of the system. - Pump trip with power controls at 0.5:0.5:0.8 - Boiler Inlet T=75°, Outlet T=69°
AUG30007	- Pump trip with power controls at 0.5:0.5:0.9 - Boiler Inlet T=75°, Outlet T=69°
AUG30008	- Pump trip with power controls at 0.5:0.8:0.5
AUG30009	- Repeat of 008 - Boiler Inlet T=76°, Outlet T=72°
AUG30010	- Pump trip with power controls at 0.5:0.5:0.85 - Boiler Inlet T=76°, Outlet T=72°
AUG30011	- Pump trip with power controls at 0.5:0.5:0.9
AUG30012	- Pump trip with power controls at 0.5:0.5:0.95
AUG30013	- Determine the effect of channels 3 to 6 boiling on the rest of the system - Pump trip with power controls at 0.5:0.75:0.75
AUG30014	- Determine the effect of channels 1 and 2 boiling on the rest of the system - Pump trip with power controls at 75:50:50
AUG30015	- pump trip with power controls at 80:50:50
AUG30016	- Pump trip with power controls at 85:50:50
AUG30017	- Determine the effect of channels 1, 2, 5, 6 boiling on the rest of the system. - Pump trip with power controls at 0.85:0.5:0.85
AUG30018	- Determine the effect of channels 1 to 4 boiling on the rest of the system. - Pump trip with power controls at 0.75:0.75:0.5

TEST	DESCRIPTION OF TEST
AUG30019	- Pump trip with power controls at 0.5:0.75:0.5
AUG30020	- Pump trip with power controls at 0.5:0.5:1.0
AUG31001	- Determine the effect of inlet subcooling on pump trip tests - Pump trip with boiler outlet temperature of 50°, power controls at 0.5:0.8:0.5 - Boiler Outlet T=50°
AUG31002	- Pump trip with boiler outlet temperature at 73°, power controls at 0.5:0.8:0.5 - Boiler Outlet T=73°
AUG31003	- Pump trip with boiler outlet temperature of 72°, power controls at 0.5:0.75:0.5 - Boiler Outlet T=72°
AUG31004	- Pump trip with boiler outlet temperature of 74°C, power controls at 0.5:0.8:0.5 - Boiler Outlet T=74°
AUG31005	- Determine the effect of initial conditions on channel 3 & 4 boiling test results - standing start with power controls at 0.5:0.7:0.5
AUG31006	- standing start with power controls at 0.7:0.5:0.5
AUG31007	- standing start with power controls at 0.5:0.5:0.7
SEP05001	- Determine the effect of header size on the outcome of pump trip test with power controls at 0.5:0.75:0.5 - all subsequent tests done without header extension - boiler $\Delta T=2°$, boiler outlet T=72°

TEST	DESCRIPTION OF TEST
SEP05002	- Pump trip with power controls at 0.5:0.75:0.5 - Boiler ΔT=2°, Boiler Outlet T=72°
SEP05003	- standing start with power controls at 0:0.5:0
SEP05004	- standing start with power controls 0:0.7:0
SEP05005	- standing start with power controls 0.7:0:0
SEP05006	- standing start with power controls 0:0:0.7
SEP05007	- Pump trip with power controls at 0.5:0.5:0.9
SEP05008	- Pump trip with power controls at 0.5:0.5:0.9 - Boiler Outlet T=72° - high feedwater flow
SEP06001	- Slow power ramp test for rig characterization - Effect of pump operation on establish flow pattern with reverse flows.
SEP06002	- Slow power ramp
SEP06003	- Slow power ramp
SEP06004	- Slow power ramp - feedwater flow = 0.5 USGPM
SEP06005	- standing start with total power of 4kW - Boiler Outlet T=68°
SEP06006	- standing start - total power = 6.3 kW - Boiler Outlet T=68°
SEP06007	- Repeat of SEP06006
SEP10001	- Channels 5 & 6 were removed from system for Sept. 10 tests - Pump trip with power controls at 0.5:0.6 - Boiler Outlet T=72° - channel ΔT=5°

TEST	DESCRIPTION OF TEST
SEP10002	- Pump trip with power controls at 0.4:0.7
SEP10003	- Pump trip with power controls at 0.5:0.8 - Boiler Outlet T=71°
SEP10005	- Repeat of test 004
SEP10006	- Pump trip with power controls at 0.7:0.7
SEP10007	- Pump trip with power controls at 0.8:0.8
SEP10008	- Slow power ramp with 2 channels per pass
SEP10009	- standing start - initial T=65° - Power = 2.8kW
SEP11001	- Rig restored to 3 channels per pass - Crash cooldown from reverse thermosyphoning conditions - test aborted because of excessive air in the system
SEP13001 to 004	- SEP13 tests were done for videotaping - tests 001-004 were pump trip tests with 3 channels per pass
SEP13005 to 007	- Pump trip and standing start tests with 2 channels per pass
SEP17001	- Experiment to test turbine flow meter - Pump trip with power controls at 0.5:0.8:0.5 - Boiler Outlet T=77°
SEP17002	- Crash cooldown from reverse thermosyphoning condition
SEP17003	- Pump trip with power controls at 0.5:0.8:0.5 - Surge tank hot

TEST	DESCRIPTION OF TEST
SEP17004	- Test for "figure of 8" flow oscillations - Rig run at full power and pump speed decreased until boiling begins
SEP19001	- Fast power ramp from single phase thermosyphoning starting condition
SEP19002	- Pump trip with power controls at 0.5:0.8:0.5 - Boiler Outlet T=80°
SEP19003	- Repeat of 002 with boiler Outlet T=72°
SEP19004	- Pump trip with power controls at 0.5:0.5:0.8
SEP19005	- standing start with power controls at 60:75:60
SEP19006	- Pump trip with power controls at 0.75:0.75:0.75 - Boiler Outlet T=74° - Crash Cooldown
SEP19007	- Repeat of 006
SEP19008	- Repeat of 006
SEP19009	- Pump trip with power controls at 0.5:0.8:0.5
SEP19010	- Repeat of 006
SEP19011	- Repeat of 009
SEP19012	- Repeat of 006
SEP19013	- standing start with power controls at 0.75:0.75:0.75
SEP19014	- Repeat of 009
SEP19015	- Repeat of 009
SEP19016	- Repeat of 009 with system pressure at 33 kPa (g)
SEP19017	- Repeat of 009 with system pressure at 0 kPa (g)

APPENDIX C

ADDITIONAL TESTS USING LONGER FEEDER PIPES

1.0 INTRODUCTION

After the original tests, described in the main report, were completed, further tests were requested to investigate the effect of feeders with long horizontal sections. The rig was modified so that on channels 3 and 4, the inlet and outlet feeders had significantly increased horizontal sections. The final configuration is as indicated in Figure 1.

At the same time, the rig was demonstrated to a number of organizations. At this demonstration, the tests indicated in the attached note, were carried out. Finally, a video tape was made that contains a description of the test rig and a typical test.

2.0 TESTS CARRIED OUT

Test	Description
OCT19001	Powers 50, 75, 50, T_{in} = 74°C ΔT = 3°C
OCT19002	Powers 50, 80, 50, T_{in} = 74°C ΔT = 3°C
OCT19003	Powers 50, 80, 50, T_{in} = 70°C ΔT = 6°C
OCT19004	Powers 70, 70, 70, T_{in} = 74°C ΔT = 3°C
OCT19005	Powers 75, 75, 75, T_{in} = 66°C ΔT = 7°C
OCT19006	Powers 85, 85, 85, T_{in} = 65°C ΔT = 8°C Pumps on at 1300 secs for short while
OCT19007	Power 85, 85, 85, T_{in} = 72°C ΔT = 5°C Boiler 0.8 USGPM Pipe break at 1492 sec. Channel 6 inlet
OCT23001	Power 50, 75, 50, T_{in} about 74°, ΔT about 2°C (Preparation tests for demonstration)
OCT23002	Power 50, 85, 50
OCT23003	Power 50, 85, 50
OCT23004	Power 50, 95, 50
OCT24001	Power 50, 50, 85

OCT24002	Power 85, 50, 50	
OCT24003	Power 85, 95, 85	air in boiler
OCT24004	Power 85, 95, 85	

DEMO 1 TO 9 were tests carried out during the demonstration

OCT29001	Power 50, 85, 50	$\Delta T = 3°$
OCT29002	Power 50, 85, 50	$\Delta T = 5°$
OCT29003	Power 50, 85, 50	$\Delta T = 8°$
OCT29004	Power 50, 85, 50	$\Delta T = 10°$
	Power lowered from 85 to 50 at the start of these tests on channels 1, 2 and 5, 6	
OCT29005	Repeat of 29004	
OCT29006	" "	
OCT29007	" "	
OCT29008	" "	
	Air removed from boilers	
OCT29009	Power 50, 80, 50	repeat of 29004
OCT29010	Low Inventory test	
OCT30001	Two channel tests Power 70, 70	$T_{in} = 68°C$ $\Delta T = 4°$
OCT30002	Power 80, 80	
OCT30003	Power 90, 90	
OCT30004	Repeat of 30002	Air removed from boiler
OCT30005	Power 50, 80	$\Delta T = 8°$
OCT30006	Repeat of 30005	
OCT30007	Repeat of 30005	
OCT30008	Power 50, 85	$\Delta T = 8°C$

OCT30009	Three channel Tests Power 50, 80, 50 T_{in} = 74°, ΔT = 6°C
OCT30010	Repeat of 30009
OCT30011	Power 50, 80, 0 T_{in} = 67°, ΔT = 10°
OCT30012	Power 90, 90, 0 T_{in} = 66°, ΔT = 6°

3.0 BOARD PRESENTATION

The overall project was described at the seminar presented to Board staff on November 2, 1984, at the Board offices. The presentation consisted of a video tape plus a discussion on some typical transients. Plots of the transients discussed are given in Figure A3-0 to A3-24. A brief description of each plot is given below.

Figure Number	Description
A3 - 0	Test results obtained during the video recording
A3 - 1	Channel Equivalent Powers 1.1%, 1.6%, 1.1%
A3 - 2	Channel Equivalent Powers 1.1%, 1.8%, 1.1%
A3 - 3	Channel Equivalent Powers 1.1%, 2.1%, 1.1%
A3 - 4	Data obtained from previous three tests
A3 - 5	Channel Equivalent Powers 1.8%, 2.1%, 1.8%
A3 - 6	Same as A3 - 5 but with air in boilers
A3 - 7	Low Inventory Results
A3 - 8	Typical result, similar to Figure 4.2.2-2, showing high heater temperature. Probably due to high flow resistance in the outlet.
A3 - 9	Test showing repeatability with A3 - 2
A3 - 10	Test showing repeatability with A3 - 3
A3 - 11 to A3 - 14	Short Feeder results, power 50, 80, 50, should all be the same

A3 - 15 and A3 - 22	Long Feeder results, power 50, 80, 50 Note longer plateaux, before flushing
A3 - 18	Long feeders, 3 channels, Power 50, 80, 0 Single Phase
A3 - 19	Long feeders, 2 channels, Power 50, 80 Single Phase
A3 - 20 and A3 - 22	Two channel, 50, 80 Two phase
A3 - 23	Three channel power 90, 90, 0
A3 - 24	Two channel power 90, 90

4.0 DATA DESCRIPTION

The list of data and Fortran files, that are on the tape given to Board staff is shown in Table A4 - 1. Each data file is formatted as indicated in Table A4 - 2. A total of 30 variables are stored each time step. The actual format is TIME, Var(I), I = 1, 30

FORMAT (F7.1, 8F7.2/3(7x, 8F7.2))

The name of each variable is shown in Table A4 - 3.

```
TEST '
     5 0  81 43  76 21  28 10  27 73  77 57  81 28  24 64  26 15
          74 98  81 19  29 50  28 85  80 84  75 50  20 40  63 65
          24 613340 42  26 76  16 58  31 24  24 96   5 38   5 66
          -0 15  80 84  77 66  76 34  81 26
    13 0  80 78  76 35  28 18  27 74  77 53  81 31  24 89  26 16
          75 10  81 15  29 51  28 86  80 86  75 73  20 41  63 66
          24 703202 46  26 78  16 57  31 26  24 98   5 39   5 66
          -0 15  80 69  77 76  76 37  81 51
    21 0  81 79  76 59  28 54  27 71  77 24  81 22  25 77  26 13
          75 30  81 13  29 53  28 85  80 79  75 97  20 40  63 90
          24 463327 30  26 79  16 36  31 27  24 67   5 39   5 67
          -0 15  80 73  78 00  76 55  81 79
    29 0  81 22  76 99  29 00  27 69  77 24  81 50  26 40  26 11
          75 52  81 22  29 55  28 83  80 75  76 06  20 43  63 97
          24 793334 62  26 78  16 77  31 26  25 23   5 39   5 67
          -0 15  80 86  78 24  76 73  82 03
    38 0  81 59  77 33  29 34  27 69  77 31  81 66  27 06  26 11
          75 77  81 44  29 58  28 82  80 71  76 13  20 43  64 18
          24 993333 18  26 75  17 12  31 24  25 62   5 40   5 66
          -0 15  81 04  78 44  76 86  82 21
    46 0  82 16  77 55  29 53  27 66  77 28  81 83  27 22  26 11
          75 88  81 50  29 55  28 85  80 77  76 19  20 45  64 52
          24 903342 98  26 74  17 05  31 23  25 54   5 40   5 67
          -0 15  81 24  78 71  77 12  82 47
    54 0  82 44  77 76  29 61  27 69  77 36  82 08  27 45  26 14
          76 02  81 71  29 58  28 83  80 82  76 26  20 46  64 59
          25 273343 39  26 73  17 42  31 21  25 80   5 40   5 68
          -0 15  81 26  78 76  77 31  82 48
    63 0  82 53  77 80  29 68  27 69  77 38  82 06  27 43  26 14
          76 13  81 77  29 61  28 83  80 93  76 42  20 48  64 71
          25 583343 74  26 72  17 88  31 20  26 18   5 40   5 67
          -0 15  81 29  78 74  77 38  82 31
    71 0  82 92  77 78  29 66  27 67  77 27  81 93  27 09  26 09
          76 28  81 66  29 58  28 83  81 13  76 75  20 46  64 75
          24 373343 29  26 71  14 50  31 19  23 09   3 19   2 62
          -0 15  81 31  78 62  77 56  82 26
    80 0  84 39  79 61  29 50  27 68  79 86  83 62  26 98  26 10
          76 27  81 45  29 57  28 84  81 03  75 92  20 47  64 92
          23 073342 86  26 68  13 49  31 18  22 15   3 19   2 62
          -0 15  84 43  82 03  79 92  85 14
    88 0  88 53  84 11  29 00  27 67  84 46  87 85  26 13  26 11
          76 08  81 02  29 53  28 83  80 95  73 89  20 48  65 13
          23 303343 08  26 69  13 71  31 19  22 37   3 19   2 62
          -0 15  87 96  84 71  81 86  88 70
```

TABLE A4 - 2

TYPICAL DATA FILE

1	CH. #1 OUTLET
2	CH. #2 INLET
3	CH. #5 OUTLET
4	CH #6 INLET
5	CH. #1 INLET
6	CH. #2 OUTLET
7	CH #5 INLET
8	CH. #6 OUTLET
9	CH#1 FEEDER IN
10	CH#1 FEEDER OUT
11	CH#5 FEED C/L
12	CH#5 FEED WALL
13	BOILER IN
14	BOILER OUT
15	FEED W IN
16	FEED W OUT
17	CH #2 OUTLET PRESS
18	CH #1 INLET PRESS
19	CH #2 INLET PRESS
20	INLET HEADER PRESS
21	REFERENCE PRESS
22	CH #1 OUTLET PRESS
23	UPPER POWER
24	MIDDLE POWER
25	LOWER POWER
26	CHANNEL 3 OUT
27	CHANNEL 4 IN
28	CHANNEL 3 IN
29	CHANNEL 4 OUT
30	TURBINE FLOW

TABLE A4 - 3

VARIABLES IN DATA FILES

TABLE A3 - 1
LIST OF FILES ON TAPE

Directory _MSA0

AUG23001.DAT;1	100	23-AUG-1984 10:55
AUG23002.DAT;1	55	23-AUG-1984 10:55
AUG23003.DAT;1	80	23-AUG-1984 10:55
AUG24001.DAT;1	82	24-AUG-1984 10:55
AUG28001.DAT;1	16	28-AUG-1984 10:55
AUG28002.DAT;1	25	28-AUG-1984 10:55
AUG28003.DAT;1	18	28-AUG-1984 10:55
AUG28004.DAT;1	10	28-AUG-1984 10:55
AUG28005.DAT;1	7	28-AUG-1984 10:55
AUG28006.DAT;1	17	28-AUG-1984 10:55
AUG280062.DAT;1	7	28-AUG-1984 10:55
AUG28007.DAT;1	6	28-AUG-1984 10:55
AUG28008.DAT;1	10	28-AUG-1984 10:55
AUG28009.DAT;1	21	28-AUG-1984 10:55
AUG30001.DAT;1	13	30-AUG-1984 10:55
AUG30002.DAT;1	16	30-AUG-1984 10:55
AUG30003.DAT;1	4	30-AUG-1984 10:55
AUG30004.DAT;1	5	30-AUG-1984 10:55
AUG30005.DAT;1	11	30-AUG-1984 10:55
AUG30006.DAT;1	4	30-AUG-1984 10:55
AUG30007.DAT;1	8	30-AUG-1984 10:55
AUG30008.DAT;1	7	30-AUG-1984 10:55
AUG30009.DAT;1	4	30-AUG-1984 10:55
AUG30010.DAT;1	3	30-AUG-1984 10:55
AUG30011.DAT;1	7	30-AUG-1984 10:55
AUG30012.DAT;1	10	30-AUG-1984 10:55
AUG30013.DAT;1	11	30-AUG-1984 10:55
AUG30014.DAT;1	5	30-AUG-1984 10:55
AUG30015.DAT;1	11	30-AUG-1984 10:55
AUG30016.DAT;1	7	30-AUG-1984 10:55
AUG30017.DAT;1	7	30-AUG-1984 10:55
AUG30018.DAT;1	5	30-AUG-1984 10:55
AUG30019.DAT;1	5	30-AUG-1984 10:55
AUG30020.DAT;1	8	30-AUG-1984 10:55
AUG31001.DAT;1	5	31-AUG-1984 10:55
AUG31002.DAT;1	13	31-AUG-1984 10:55
AUG31003.DAT;1	7	31-AUG-1984 10:55
AUG31004.DAT;1	29	31-AUG-1984 10:55
AUG31005.DAT;1	6	31-AUG-1984 10:55
AUG31006.DAT;2	13	31-AUG-1984 10:55
AUG31007.DAT;1	10	31-AUG-1984 10:55
BOARD.DAT;3	1	21-SEP-1984 10:55
DATAPLOT.DAT;14	1	2-OCT-1984 10:55
DEMO1.DAT;1	7	25-OCT-1984 10:55
DEMO2.DAT;1	9	25-OCT-1984 10:55
DEMO3.DAT;1	6	25-OCT-1984 10:55
DEMO4.DAT;2	9	25-OCT-1984 10:55
DEMO5.DAT;1	10	25-OCT-1984 10:55
DEMO6.DAT;2	12	25-OCT-1984 10:55
DEMO7.DAT;1	12	25-OCT-1984 10:55
DEMO8.DAT;1	12	25-OCT-1984 10:55
DEMO9.DAT;1	24	25-OCT-1984 10:55
HEATLOS.DAT;1	1	18-SEP-1984 10:55
OCT19001.DAT;1	19	19-OCT-1984 10:55
OCT19002.DAT;1	18	19-OCT-1984 10:55
OCT19003.DAT;1	8	19-OCT-1984 10:56
OCT19004.DAT;1	27	19-OCT-1984 10:56
OCT19005.DAT;1	10	19-OCT-1984 10:56

TABLE A3 - 1 CONTINUED

OCT19006.DAT;1	19	19-OCT-1984 10:56
OCT19007.DAT;1	21	19-OCT-1984 10:56
OCT23001.DAT;1	14	23-OCT-1984 10:56
OCT23002.DAT;1	12	23-OCT-1984 10:56
OCT23003.DAT;2	14	24-OCT-1984 10:56
OCT23004.DAT;1	12	23-OCT-1984 10:56
OCT24001.DAT;2	12	24-OCT-1984 10:56
OCT24002.DAT;1	14	24-OCT-1984 10:56
OCT24003.DAT;1	12	24-OCT-1984 10:56
OCT24004.DAT;1	7	24-OCT-1984 10:56
OCT29002.DAT;1	10	29-OCT-1984 10:56
OCT29003.DAT;1	10	29-OCT-1984 10:56
OCT29004.DAT;1	6	29-OCT-1984 10:56
OCT29006.DAT;1	7	29-OCT-1984 10:56
OCT29007.DAT;1	7	29-OCT-1984 10:56
OCT29008.DAT;1	7	29-OCT-1984 10:56
OCT29009.DAT;1	7	29-OCT-1984 10:56
OCT29010.DAT;1	24	29-OCT-1984 10:56
PLOTHEAD.DAT;4	1	24-OCT-1984 10:56
POWERCAL.DAT;1	1	22-AUG-1984 10:56
RIGPLOT.DAT;41	14	29-OCT-1984 10:56
SEP05001.DAT;1	5	5-SEP-1984 10:56
SEP05002.DAT;1	10	5-SEP-1984 10:56
SEP05003.DAT;1	7	5-SEP-1984 10:56
SEP05004.DAT;1	11	5-SEP-1984 10:56
SEP05005.DAT;1	4	5-SEP-1984 10:56
SEP05006.DAT;1	7	5-SEP-1984 10:56
SEP05007.DAT;1	9	5-SEP-1984 10:56
SEP05008.DAT;1	7	5-SEP-1984 10:56
SEP06001.DAT;1	43	6-SEP-1984 10:56
SEP06002.DAT;1	13	6-SEP-1984 10:56
SEP06003.DAT;2	10	6-SEP-1984 10:56
SEP06004.DAT;1	41	6-SEP-1984 10:56
SEP06005.DAT;1	9	6-SEP-1984 10:56
SEP06006.DAT;1	6	6-SEP-1984 10:56
SEP060061.DAT;3	2	6-SEP-1984 10:56
SEP06007.DAT;1	7	6-SEP-1984 10:56
SEP10001.DAT;1	7	10-SEP-1984 10:56
SEP10002.DAT;1	4	10-SEP-1984 10:56
SEP10003.DAT;1	6	10-SEP-1984 10:56
SEP10004.DAT;1	11	10-SEP-1984 10:56
SEP10005.DAT;1	9	10-SEP-1984 10:56
SEP10006.DAT;1	9	10-SEP-1984 10:56
SEP10007.DAT;1	8	10-SEP-1984 10:56
SEP10008.DAT;1	30	10-SEP-1984 10:56
SEP10009.DAT;1	10	10-SEP-1984 10:56
SEP10010.DAT;1	7	10-SEP-1984 10:56
SEP17001.DAT;1	4	17-SEP-1984 10:56
SEP17002.DAT;1	48	17-SEP-1984 10:56
SEP17003.DAT;1	4	17-SEP-1984 10:56
SEP17004.DAT;1	19	17-SEP-1984 10:56
SEP19001.DAT;1	34	19-SEP-1984 10:56
SEP19002.DAT;1	6	19-SEP-1984 10:56
SEP19003.DAT;1	14	19-SEP-1984 10:56
SEP19004.DAT;1	9	19-SEP-1984 10:56
SEP19005.DAT;1	12	19-SEP-1984 10:56
SEP19006.DAT;1	13	19-SEP-1984 10:56
SEP19007.DAT;1	6	19-SEP-1984 10:56
SEP19008.DAT;2	27	19-SEP-1984 10:56
SEP19011.DAT;1	15	19-SEP-1984 10:56
SEP19012.DAT;1	17	19-SEP-1984 10:56

TABLE A3 - 1

CONTINUED

```
SEP19013.DAT;1          36      19-SEP-1984 10:56
SEP19014.DAT;1          20      19-SEP-1984 10:56
SEP19015.DAT;1          11      19-SEP-1984 10:56
SEP19016.DAT;1           7      19-SEP-1984 10:56
SEP19017.DAT;1          12      19-SEP-1984 10:56
SIGN.DAT;34             10       3-OCT-1984 10:56
TEST1.DAT;1              1      13-SEP-1984 10:56
TEST2.DAT;1             12      13-SEP-1984 10:56
TEST3.DAT;1             20      13-SEP-1984 10:56
TEST4.DAT;1             19      13-SEP-1984 10:56
TEST5.DAT;1              5      13-SEP-1984 10:57
TEST6.DAT;1              9      13-SEP-1984 10:57
TEST7.DAT;1              6      13-SEP-1984 10:57
VIDEO.DAT;1             46      26-OCT-1984 10:57
RIGPLOT.FOR;10           4      27-JUN-1984 10:57
RIGPLOTP.FOR;19          4       3-OCT-1984 10:57
SIGN.FOR;14              1       3-OCT-1984 10:57
SIGNPLOT.FOR;11          4      18-SEP-1984 10:57
VIDEO.FOR;13             5      14-SEP-1984 10:57
VT100.FOR;5              6      21-AUG-1984 10:57
VT1001.FOR;56            6      17-SEP-1984 10:57

Total of 140 files, 1869 blocks
```

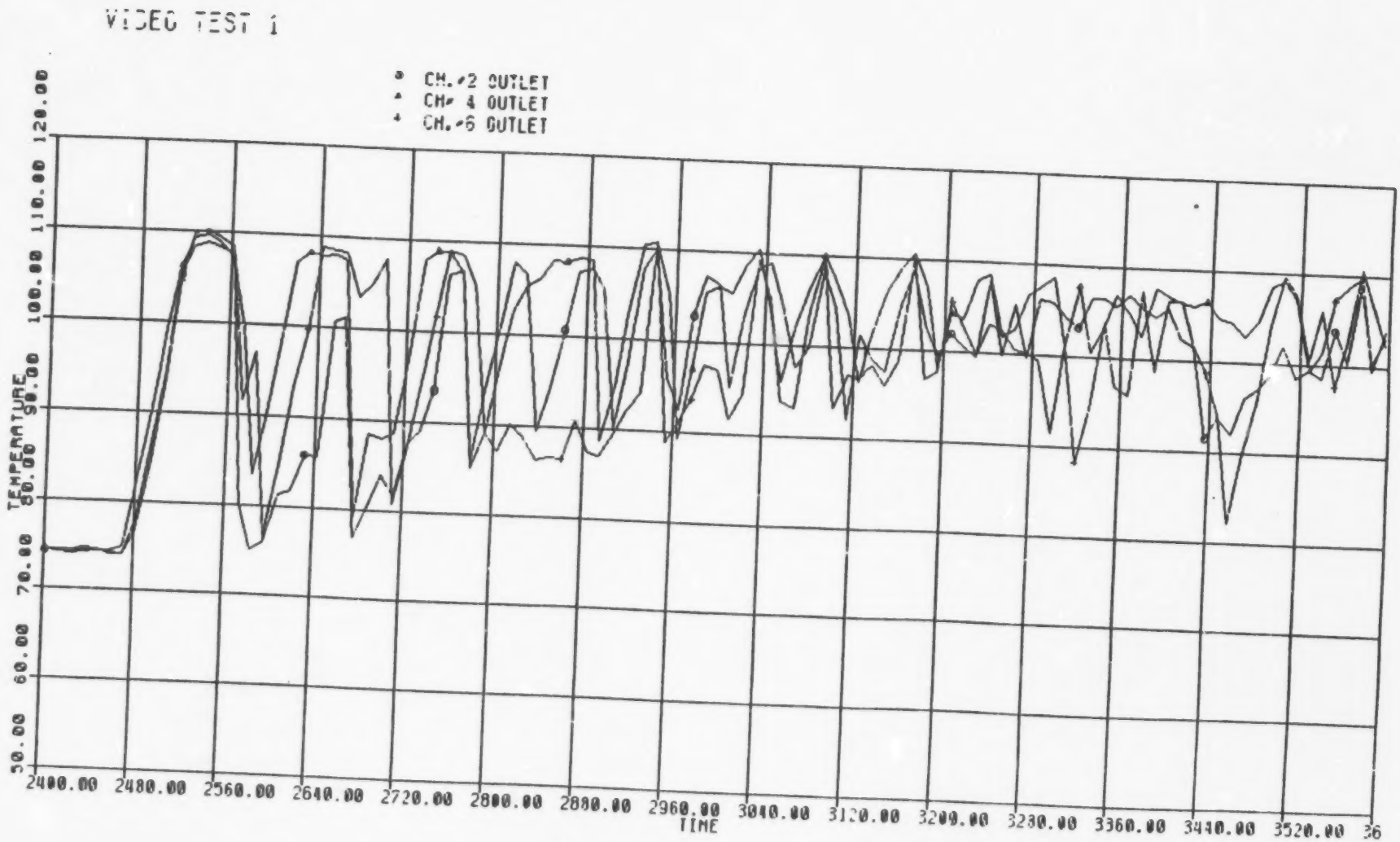

VIDEO TEST 1
CH.#2 OUTLET
CH# 4 OUTLET
CH.#6 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
2400.00
2480.00
2560.00
2640.00
2720.00
2800.00
2880.00
2960.00
3040.00
3120.00
3200.00
3280.00
3360.00
3440.00
3520.00
TIME

FIGURE A3 - 0

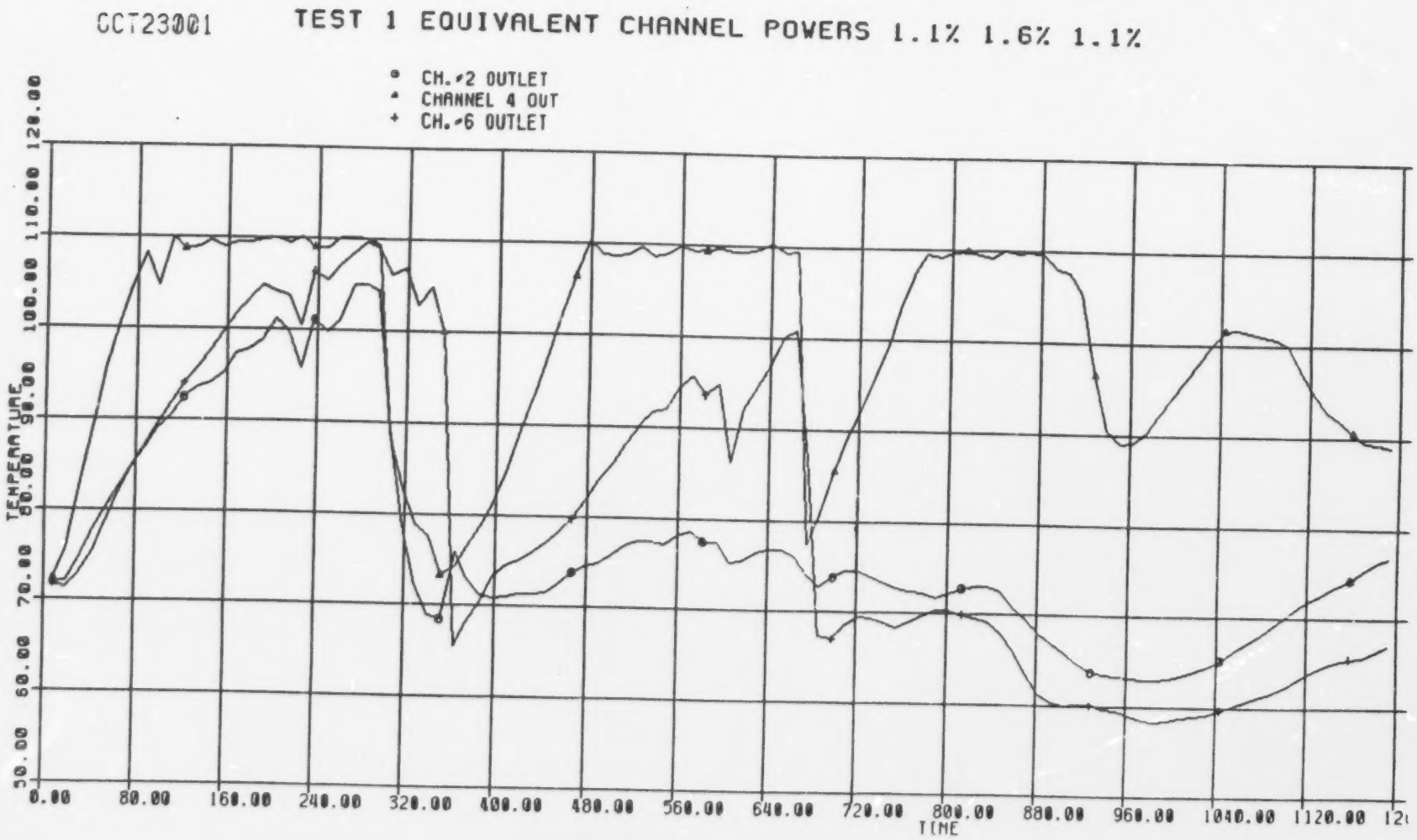

CCT23001
TEST 1 EQUIVALENT CHANNEL POWERS 1.1% 1.6% 1.1%
CH.#2 OUTLET
CHANNEL 4 OUT
CH.#6 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
720.00
800.00
880.00
960.00
1040.00
1120.00
TIME

FIGURE A3 - 1

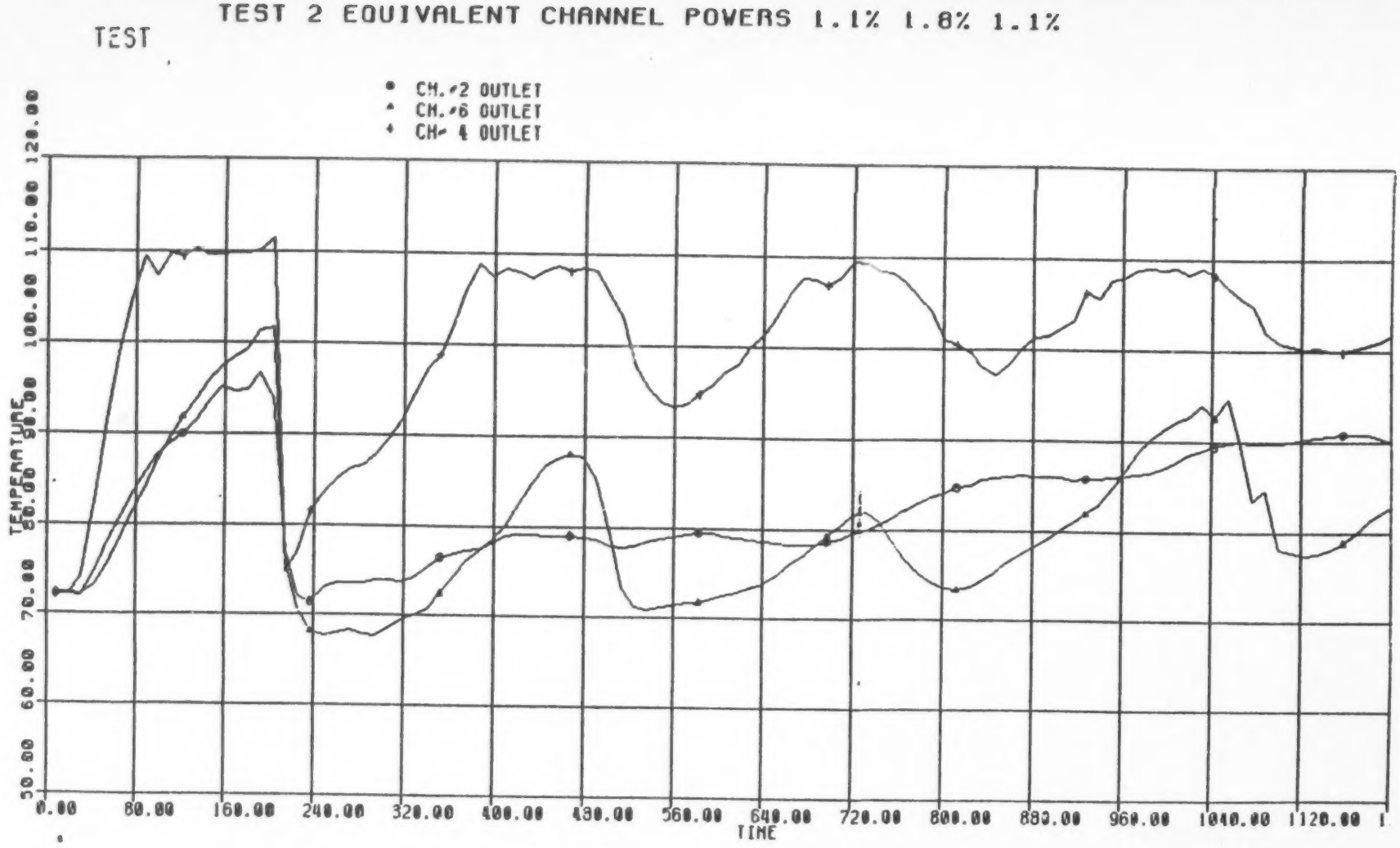

TEST 2 EQUIVALENT CHANNEL POWERS 1.1% 1.8% 1.1%
TEST
CH.#2 OUTLET
CH.#6 OUTLET
CH# 4 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
720.00
800.00
880.00
960.00
1040.00
1120.00
TIME

FIGURE A3 - 2

TEST 3 EQUIVALENT CHANNEL POWERS 1.1% 2.1% 1.1%

OCT23004

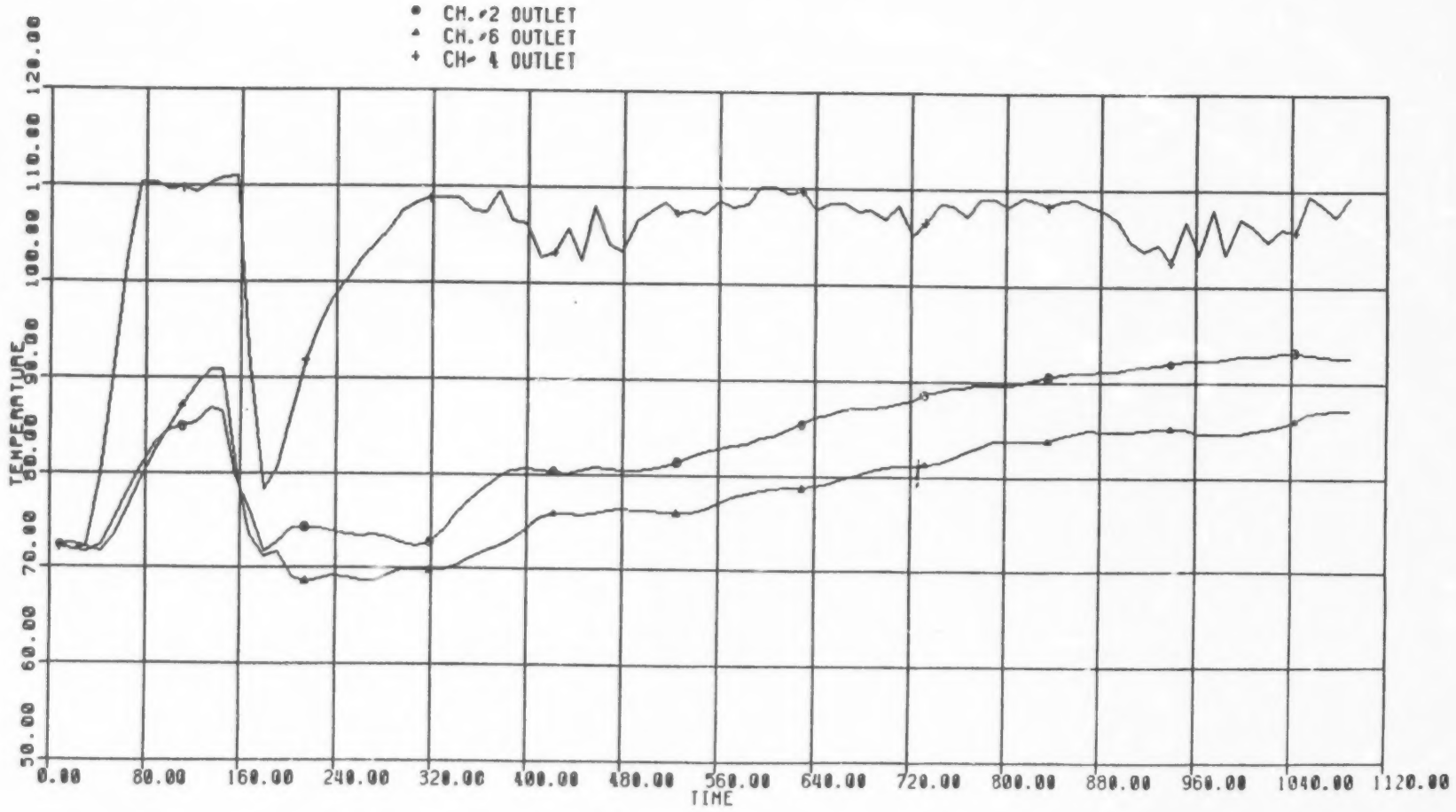


FIGURE A3 - 3

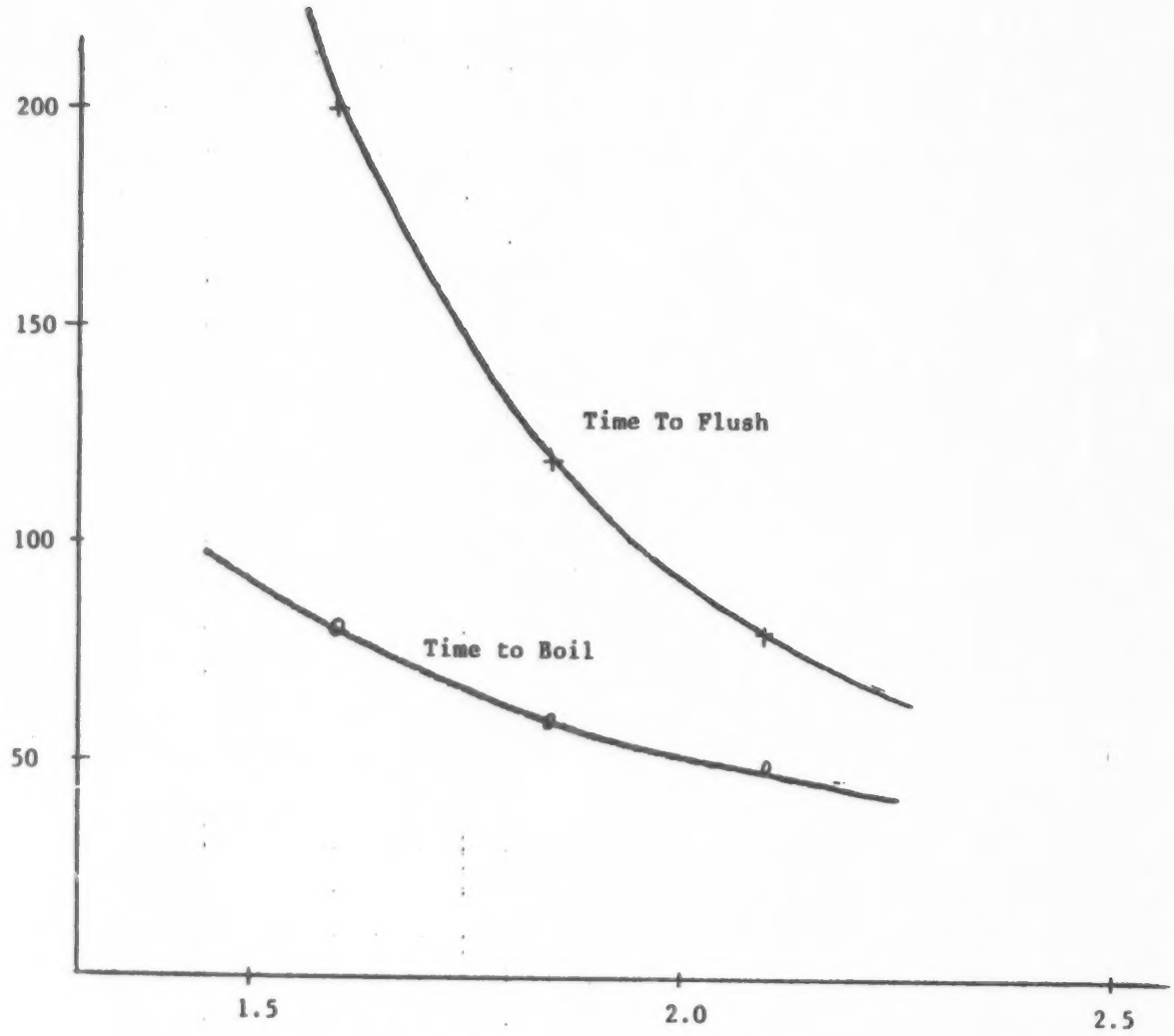

200
150
100
50
Time To Flush
Time to Boil
1.5
2.0
2.5
CENTER CHANNEL POWER (% Full Power)
TOP & BOTTOM AT 1.1%

FIGURE A3 - 4

TEST 7 EQUIVALENT CHANNEL POWERS 1.8% 2.1% 1.8%

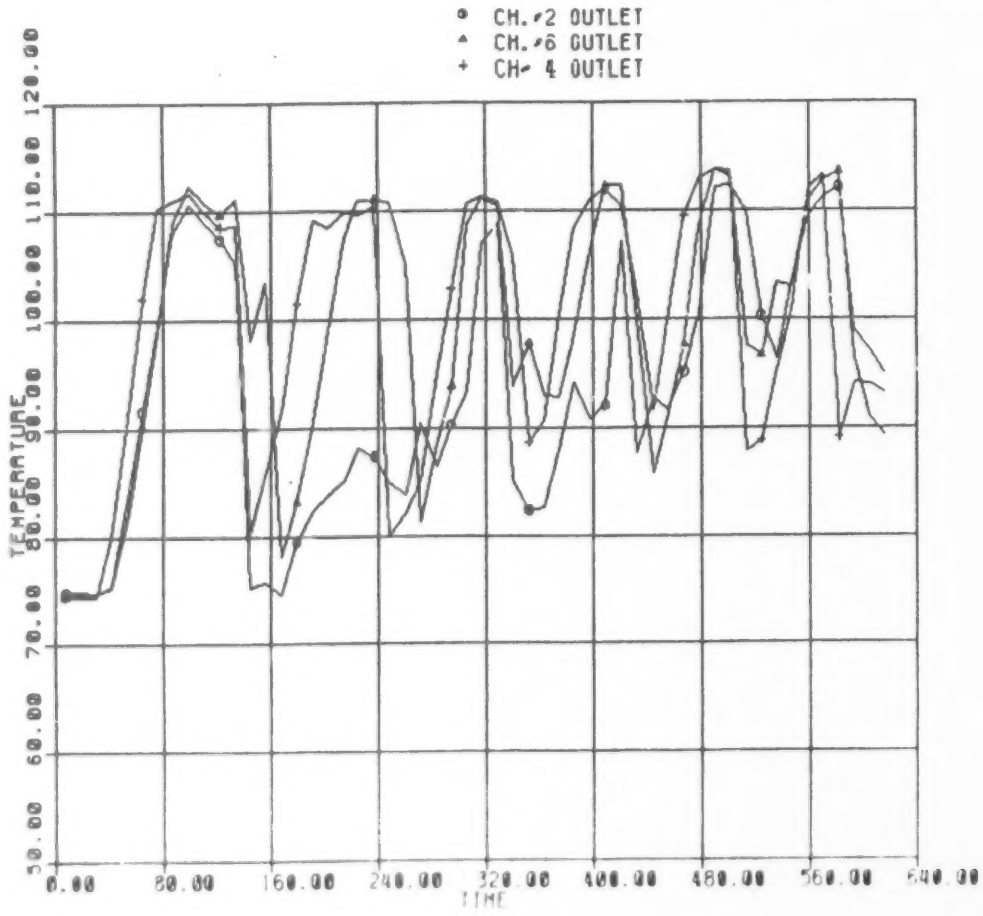


FIGURE A3 - 5

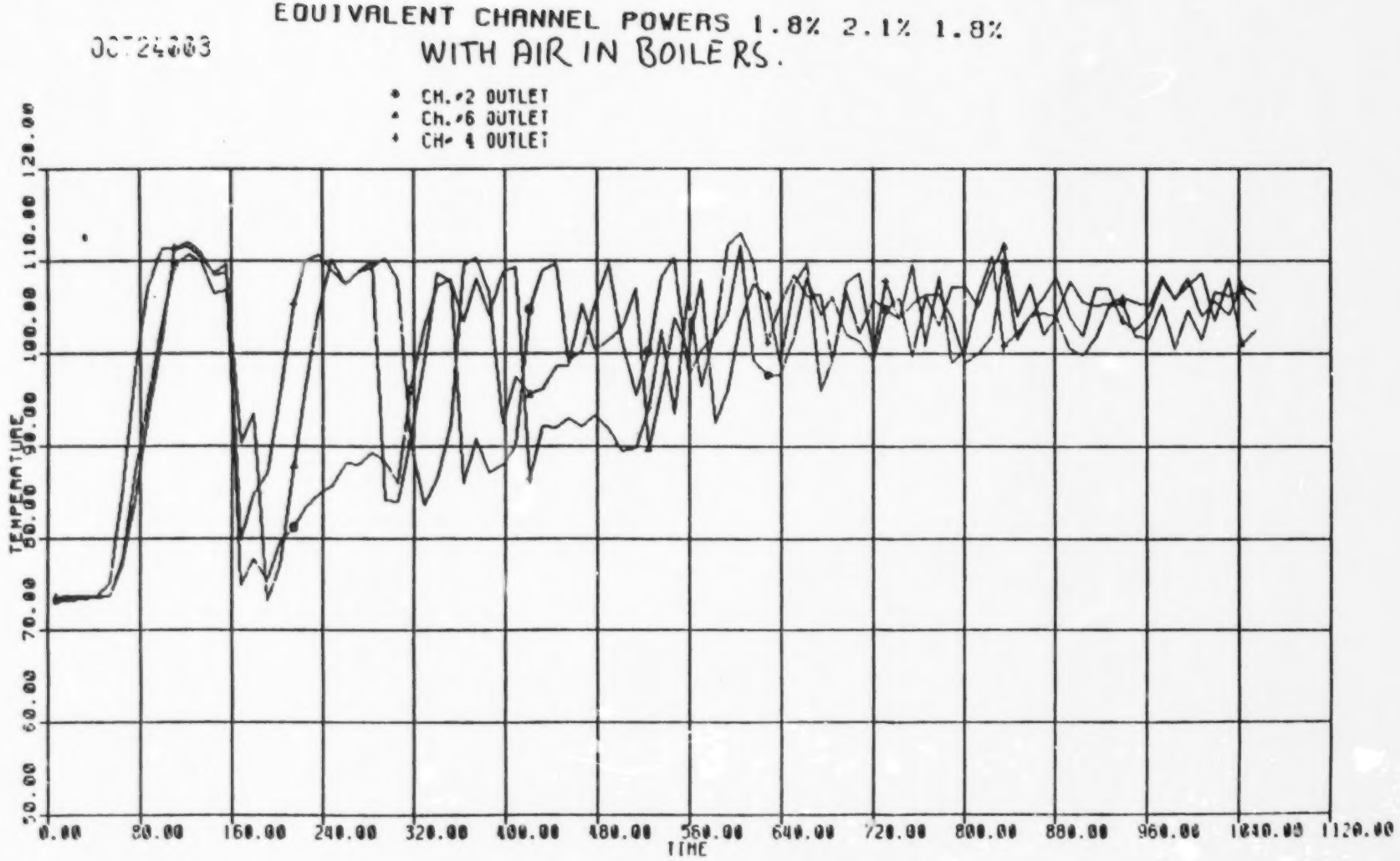

EQUIVALENT CHANNEL POWERS 1.8% 2.1% 1.8%
WITH AIR IN BOILERS.
CH.#2 OUTLET
Ch.#6 OUTLET
CH# 4 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
720.00
800.00
880.00
960.00
1040.00
1120.00
TIME

FIGURE A3 - 6

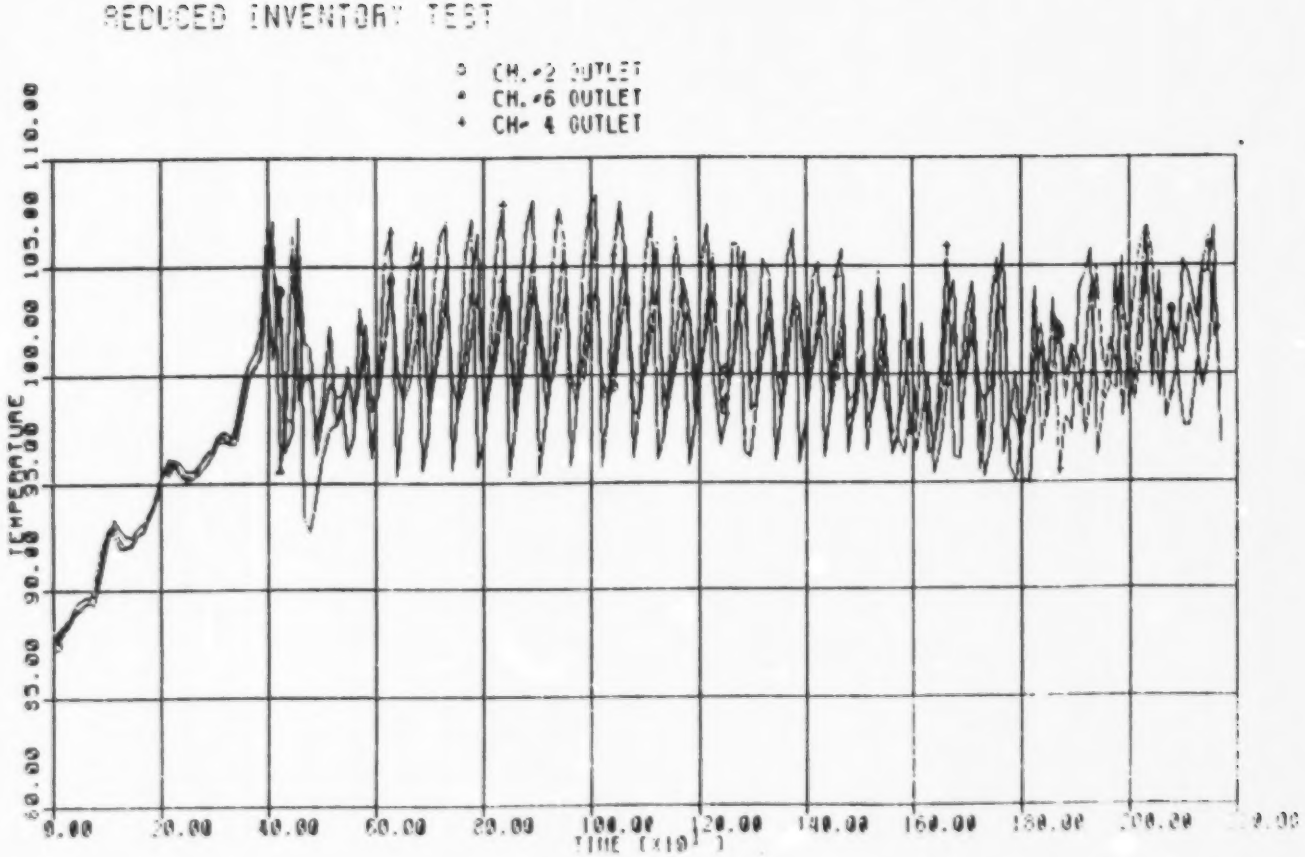

REDUCED INVENTORY TEST
CH.#2 OUTLET
CH.#6 OUTLET
CH# 4 OUTLET
TEMPERATURE
60.00
80.00
90.00
100.00
105.00
110.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
TIME (x10)

FIGURE A3 - 7

TEST 3

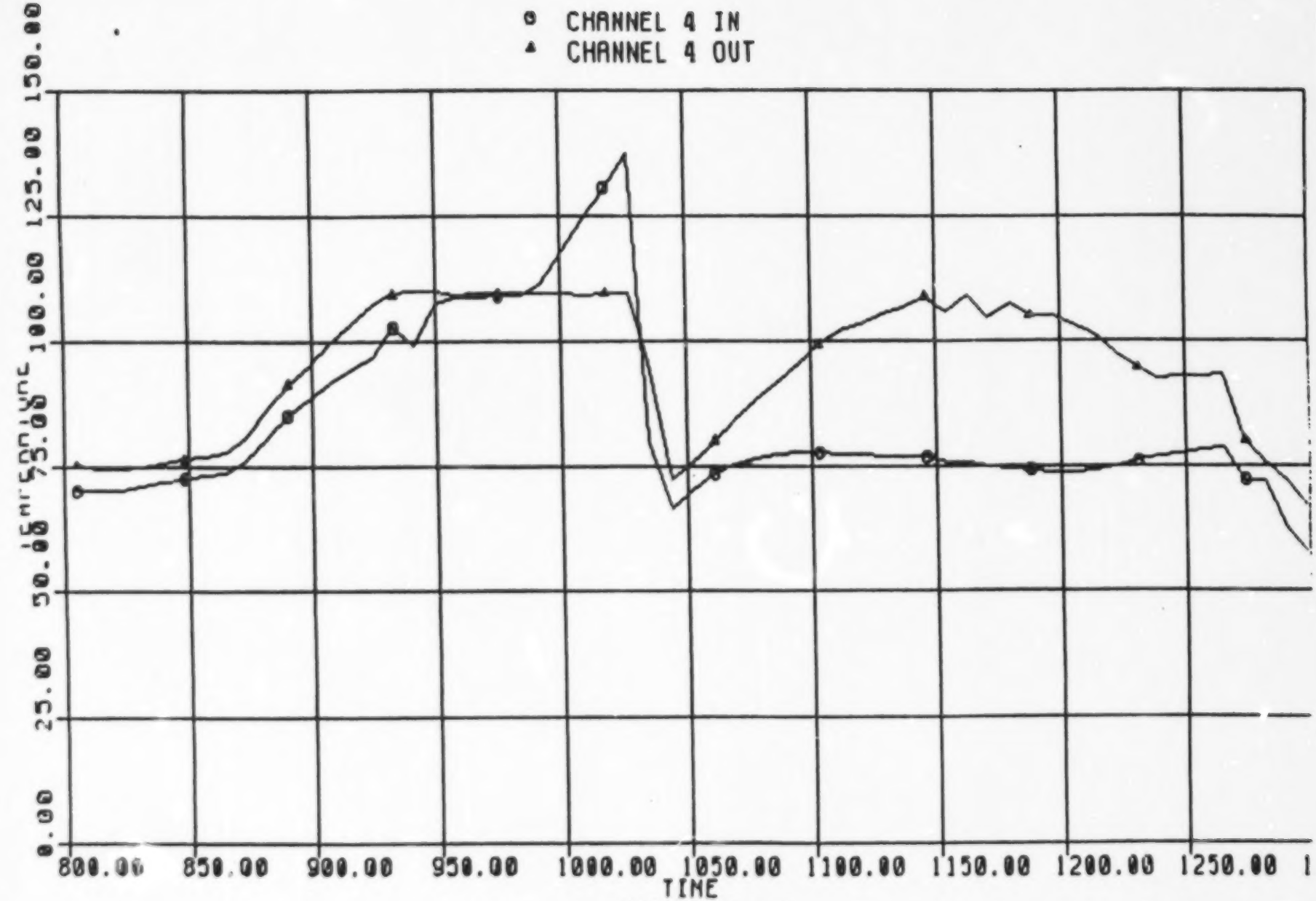


FIGURE A3 - 8

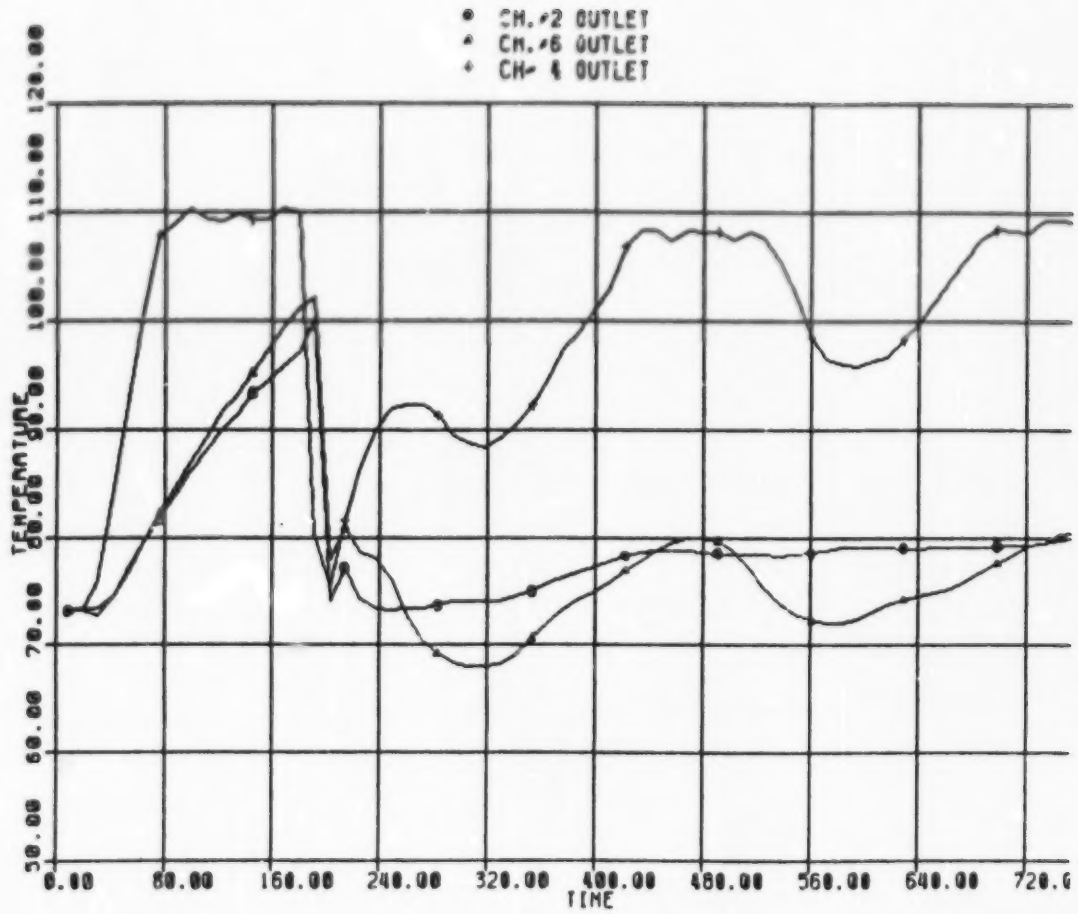

DEMO2
CH.#2 OUTLET
CH.#6 OUTLET
CH-4 OUTLET
TEMPERATURE
30.00
60.00
70.00
90.00
100.00
110.00
120.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
720.0
TIME

FIGURE A3 - 9

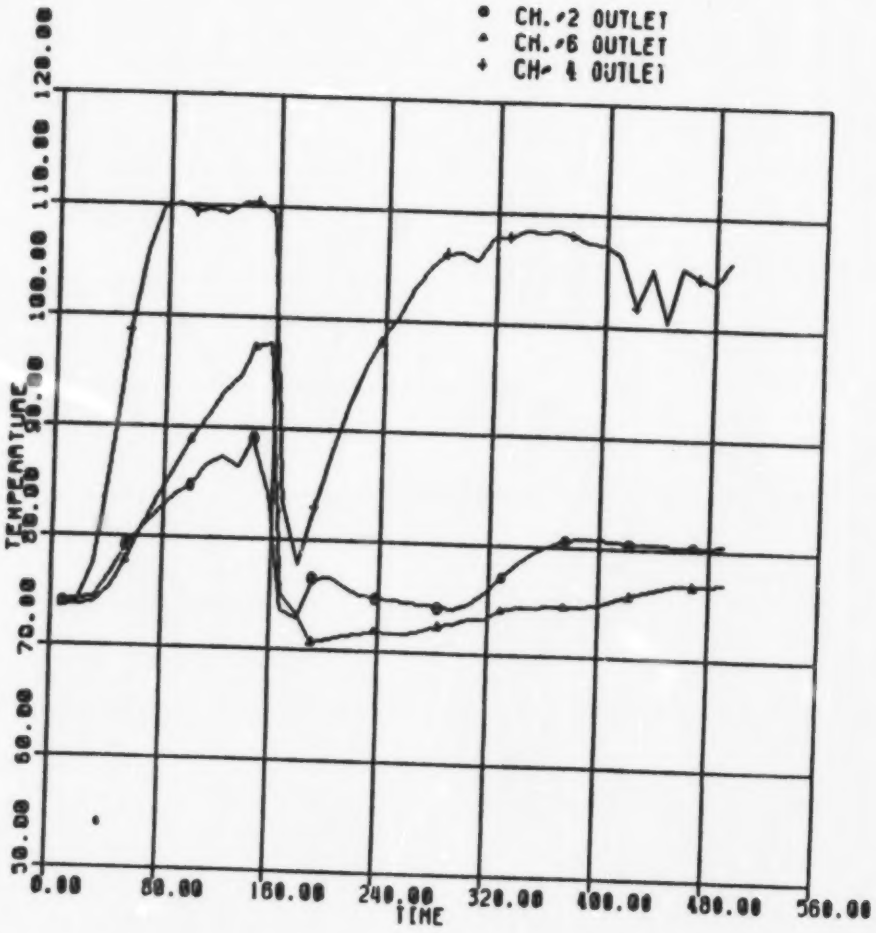

DEMO3
CH.#2 OUTLET
CH.#6 OUTLET
CH.# 4 OUTLET
TEMPERATURE
30.00
50.00
70.00
90.00
100.00
110.00
120.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
TIME

FIGURE A3 - 10

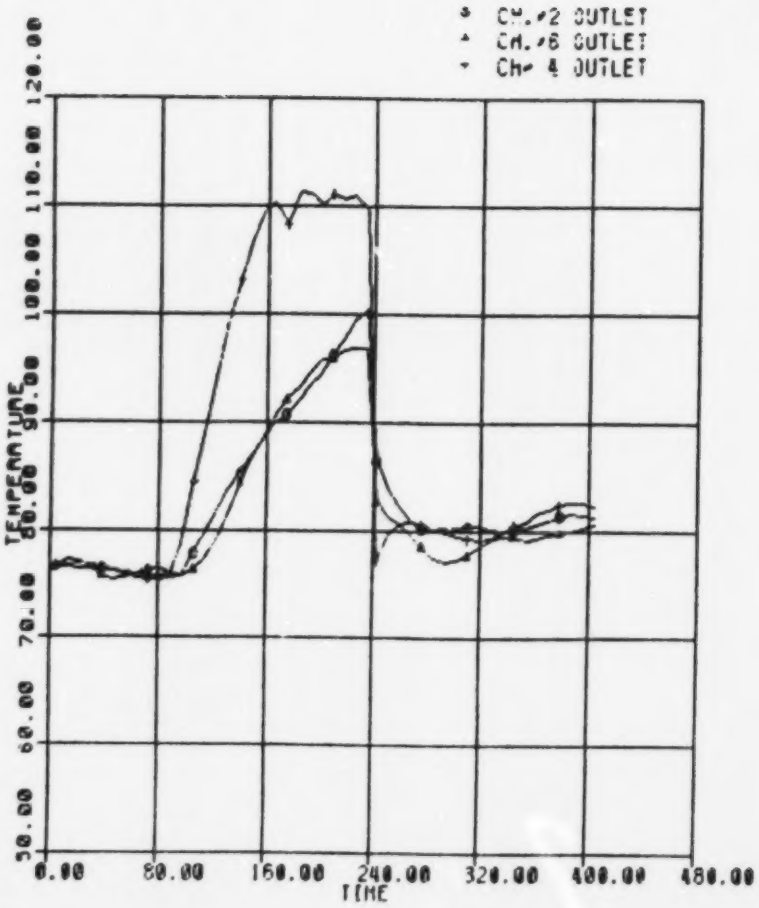

SEP.1981
CH.#2 OUTLET
CH.#8 OUTLET
CH# 4 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
TIME

FIGURE A3 - 11

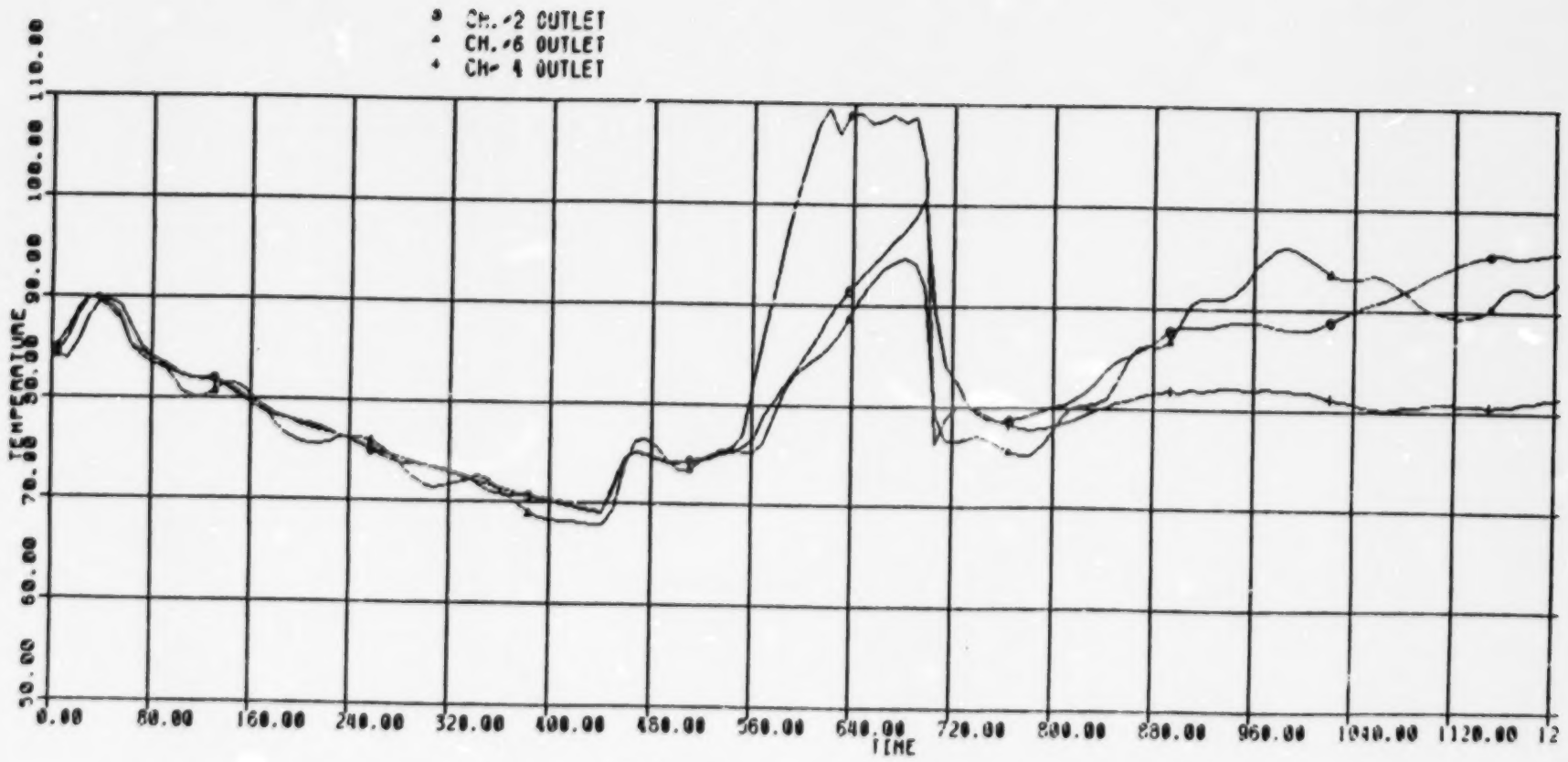

SEP:9014
CH.#2 OUTLET
CH.#6 OUTLET
CH# 4 OUTLET
TEMPERATURE
30.00
50.00
70.00
90.00
100.00
110.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
720.00
800.00
880.00
960.00
1040.00
1120.00
TIME

FIGURE A3 - 12

SEP19015

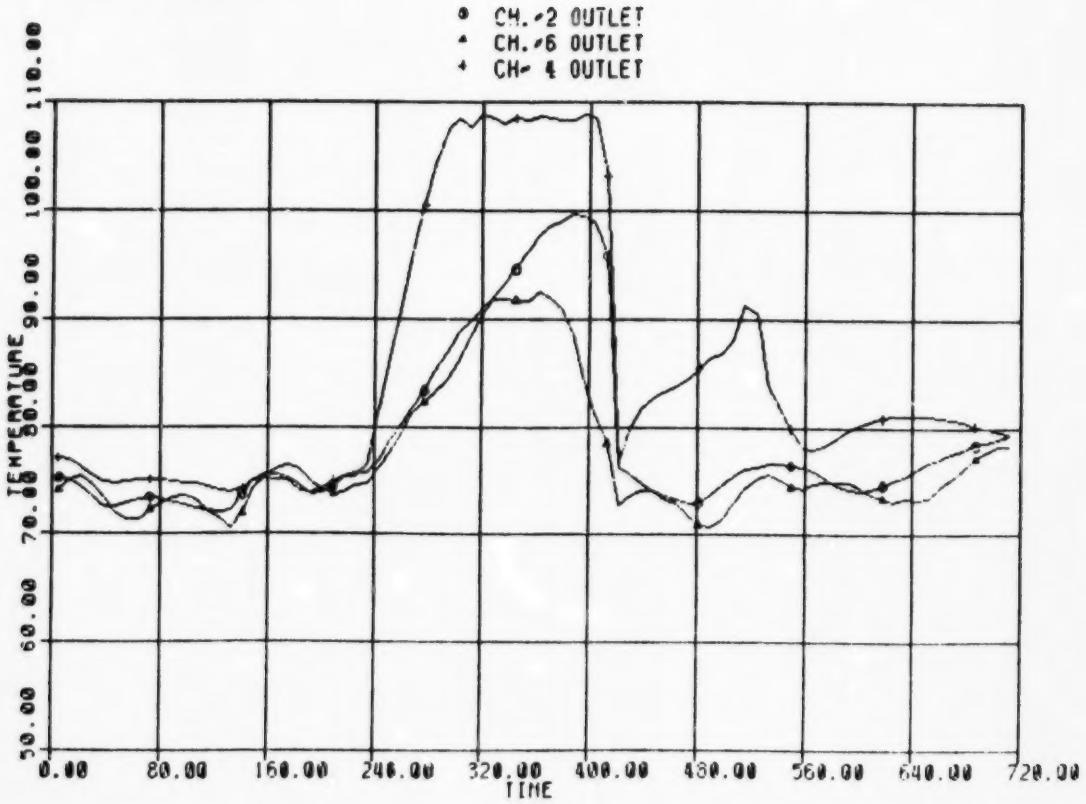


FIGURE A3 - 13

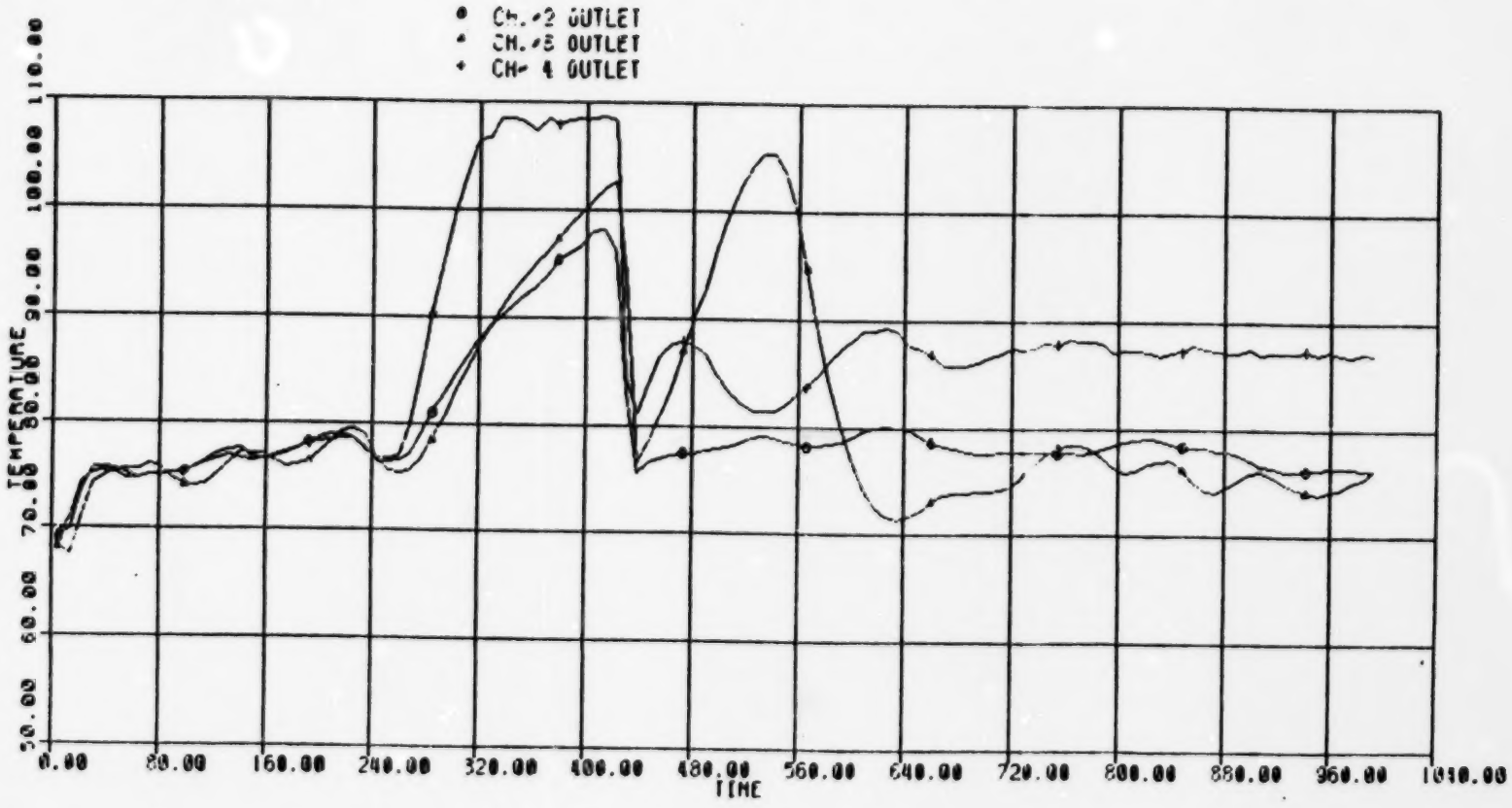

SEP19011
CH.#2 OUTLET
CH.#3 OUTLET
CH# 4 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
720.00
800.00
880.00
960.00
1040.00
TIME

FIGURE A3 - 14

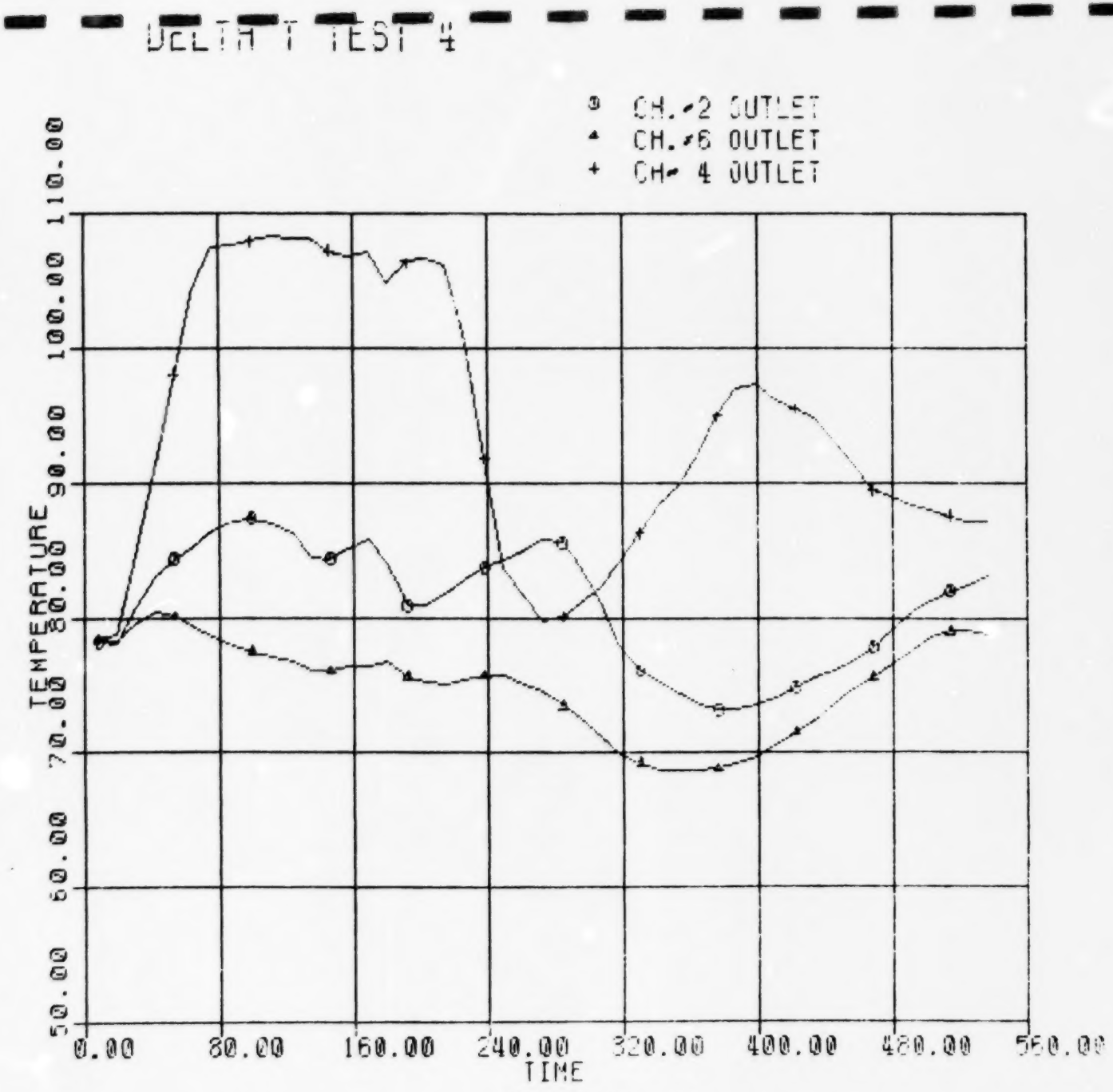

DELTA T TEST 4
CH.-2 OUTLET
CH.-6 OUTLET
CH- 4 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
TIME

FIGURE A3 - 15

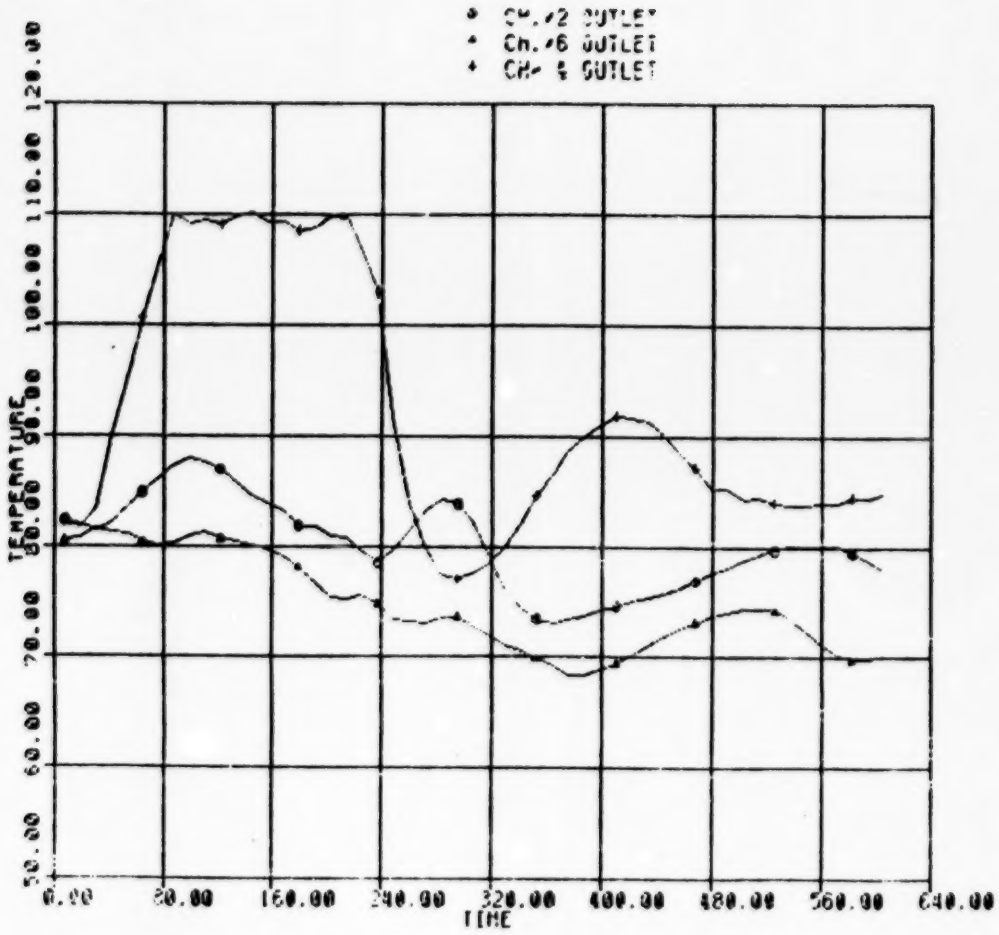

Ch.#2 OUTLET
Ch.#6 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
TIME

FIGURE A3 - 16

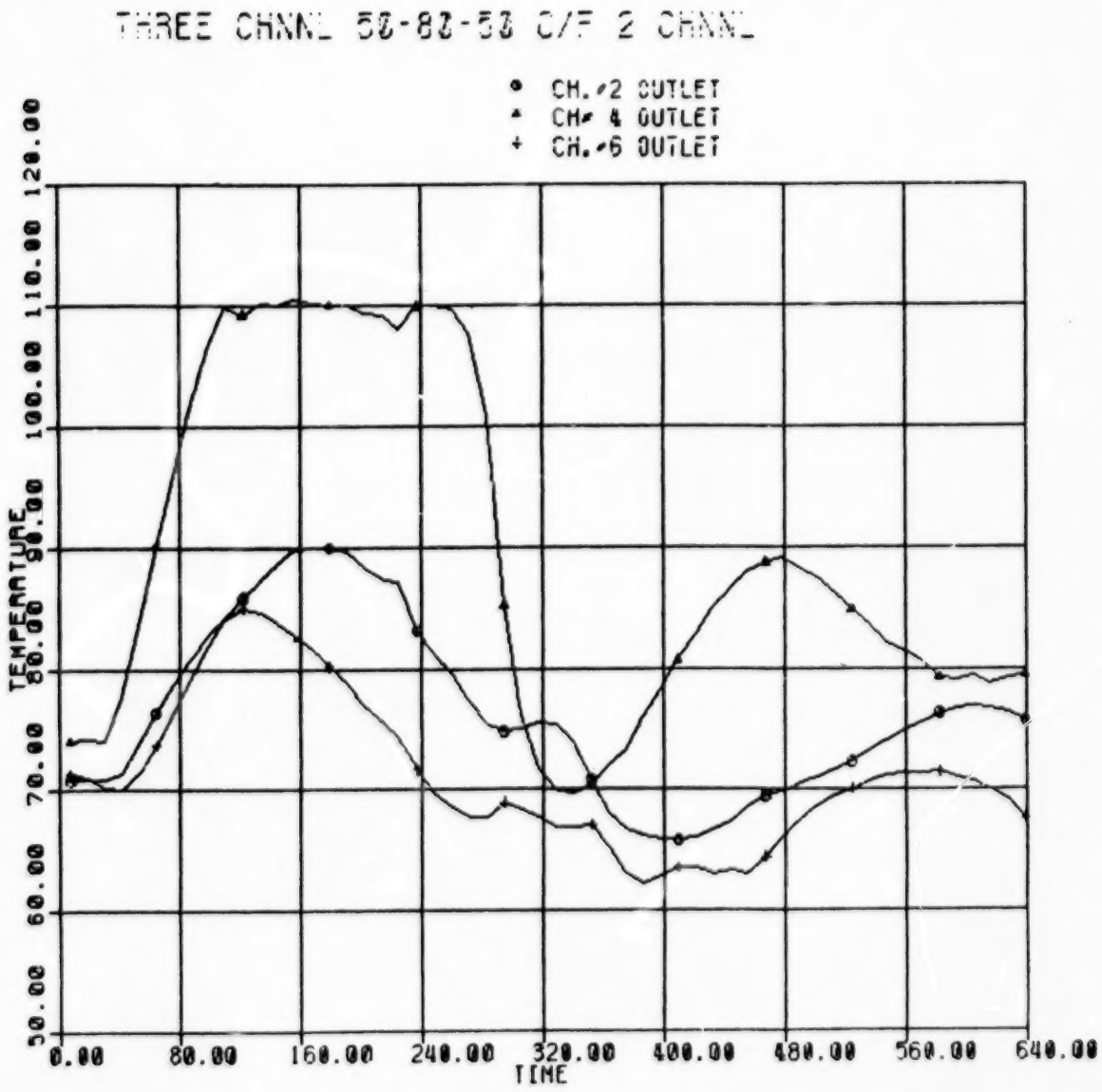

THREE CHNNL 50-80-50 C/F 2 CHNNL
CH.#2 OUTLET
CH.# 4 OUTLET
CH.#6 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
TIME

FIGURE A3 - 17

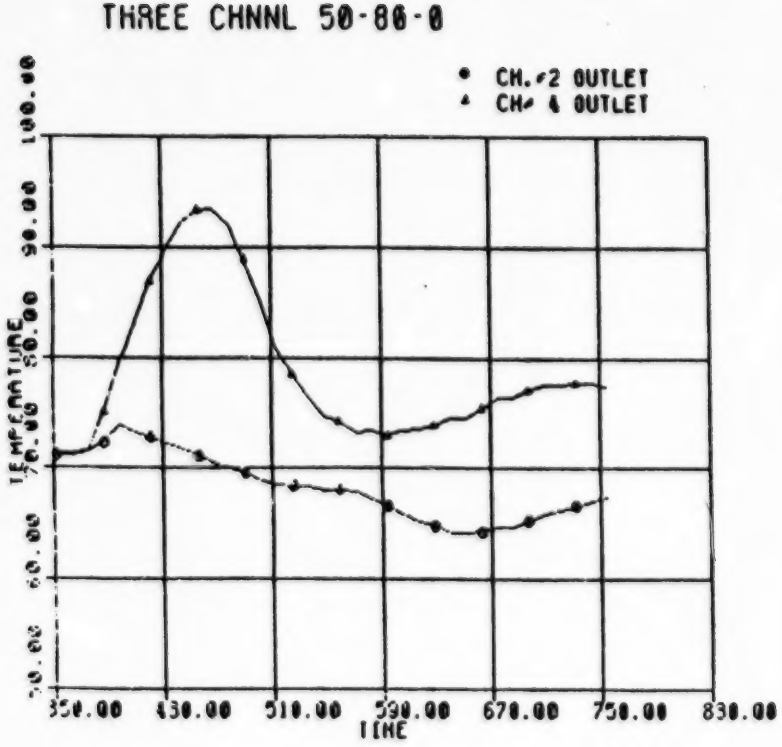

THREE CHNNL 50-80-0
CH.#2 OUTLET
CH# 4 OUTLET
TEMPERATURE
90.00
100.00
430.00
510.00
590.00
670.00
750.00
830.00
TIME

FIGURE A3 - 18

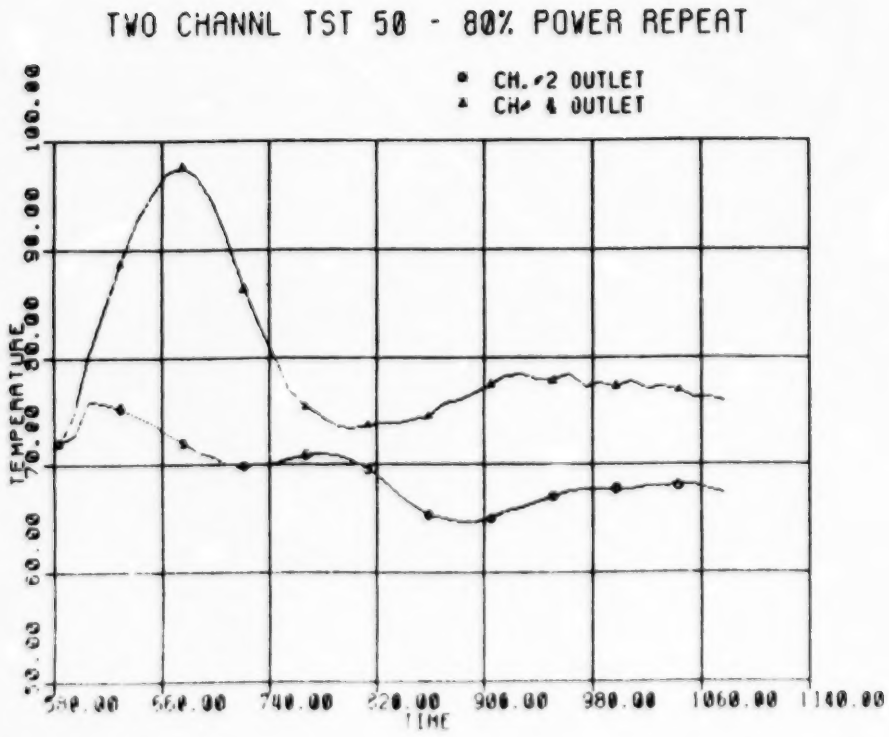
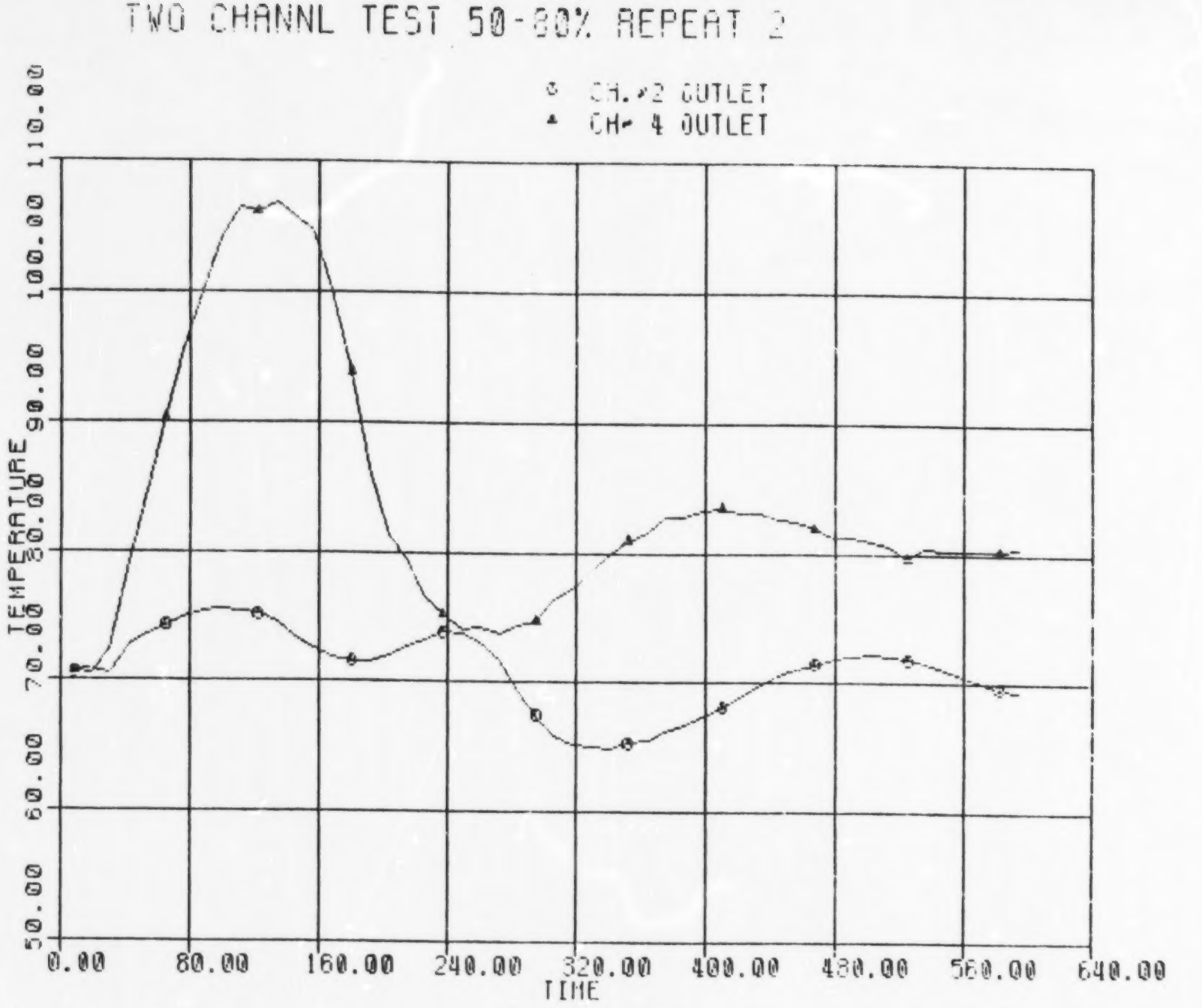

TWO CHANNL TST 50 - 80% POWER REPEAT
CH. #2 OUTLET
CH# 4 OUTLET
TEMPERATURE
100.00
90.00
80.00
70.00
60.00
50.00
660.00
740.00
820.00
900.00
980.00
1060.00
1140.00
TIME

FIGURE A3 - 19


TWO CHANNL TEST 50-80% REPEAT 2
CH.#2 OUTLET
CH- 4 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
TIME

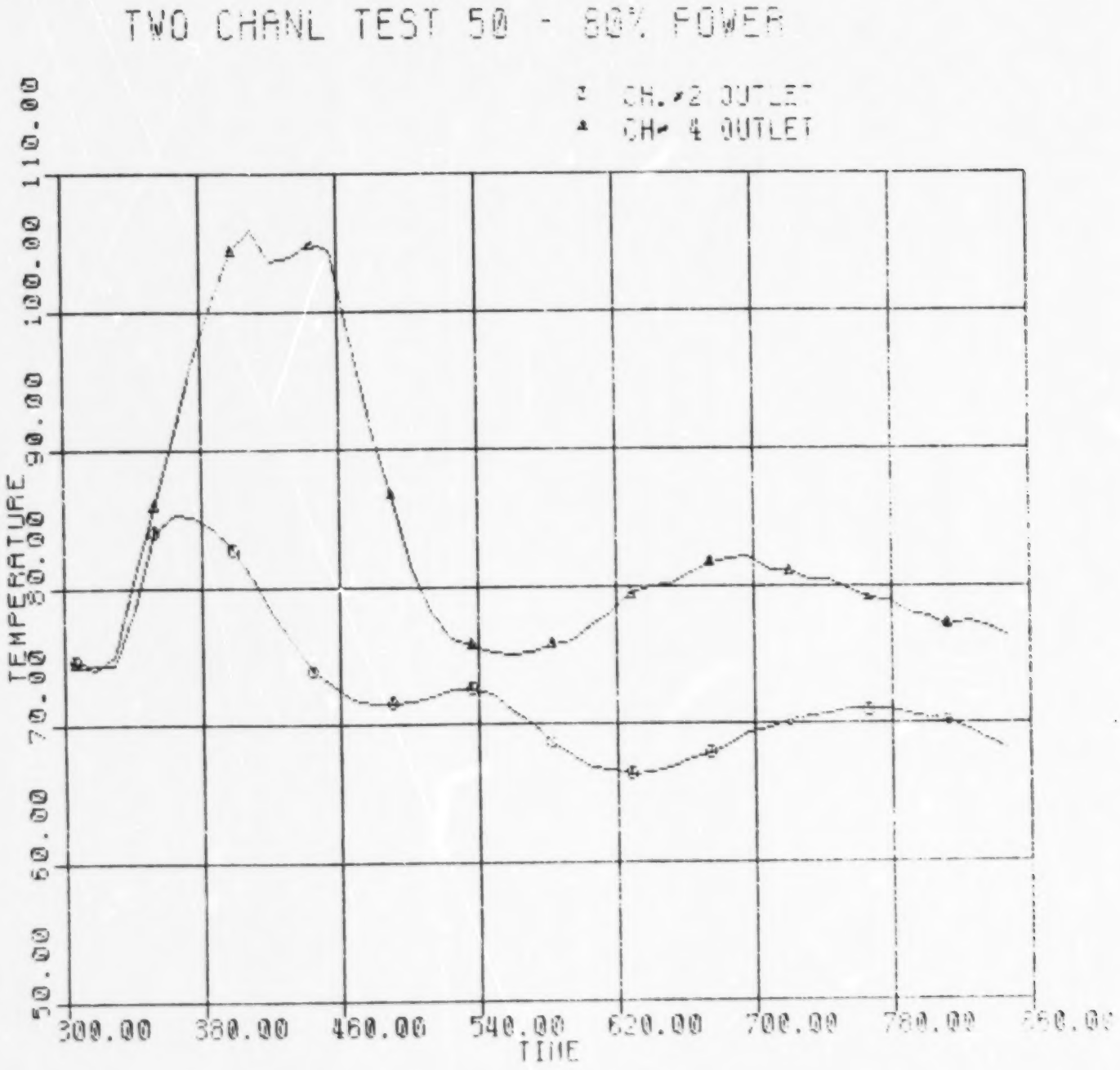

TWO CHANL TEST 50 - 80% POWER
CH.#2 OUTLET
CH# 4 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
300.00
380.00
460.00
540.00
620.00
700.00
780.00
TIME

FIGURE A3 - 21

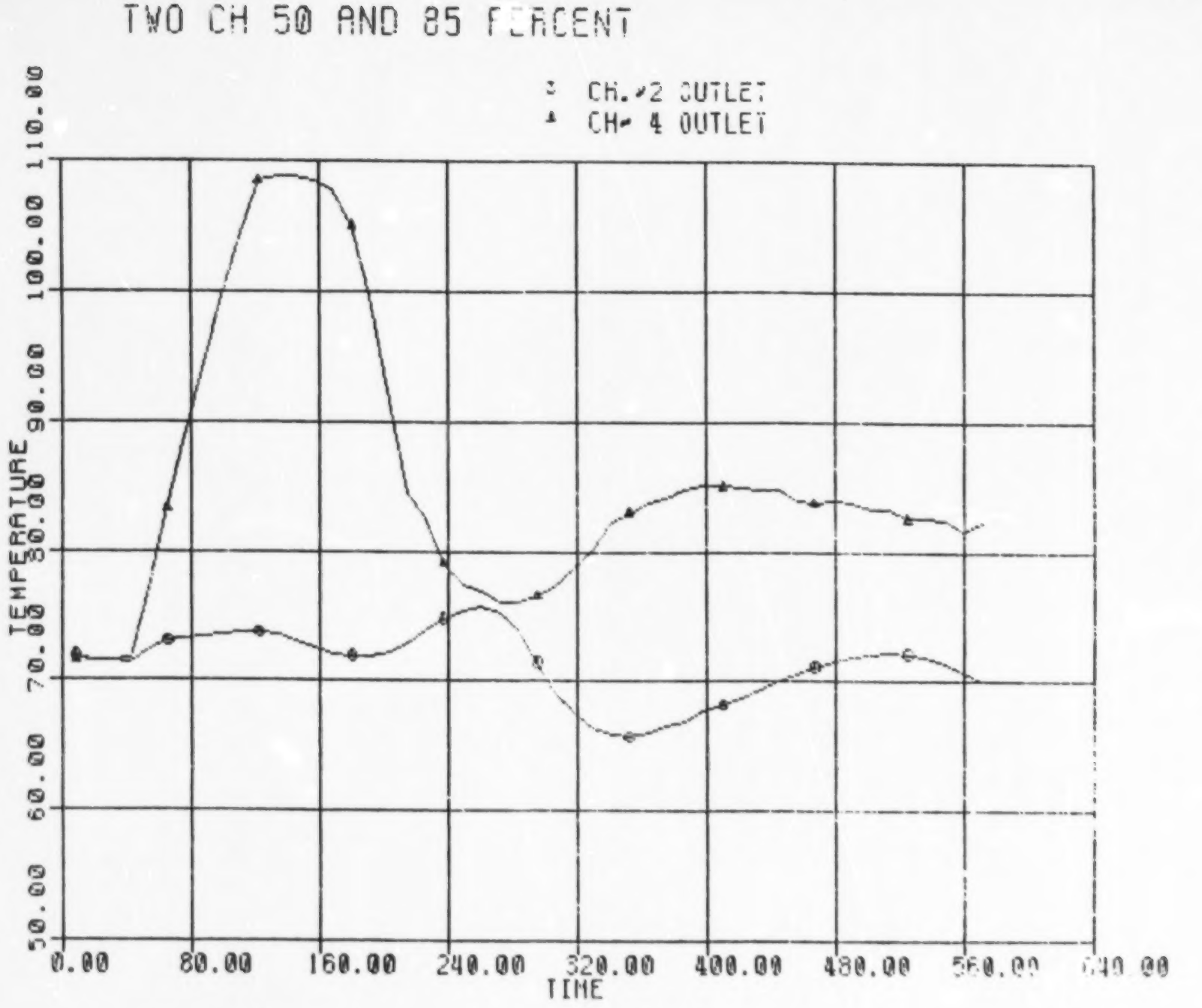

TWO CH 50 AND 85 PERCENT
CH. 2 OUTLET
CH- 4 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
TIME

FIGURE A3 22

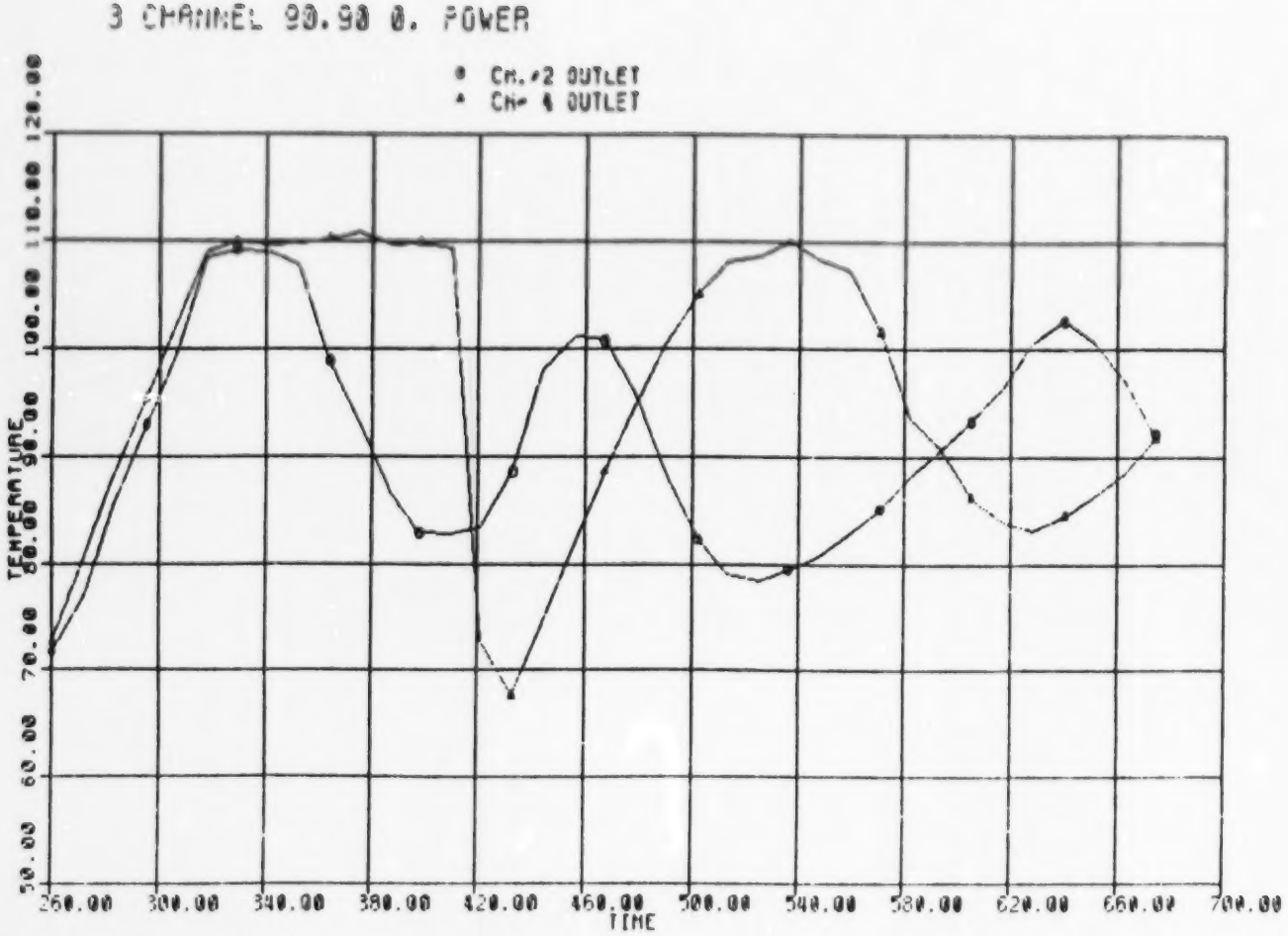

3 CHANNEL 90.90 0. POWER
CH. #2 OUTLET
CH. 4 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
260.00
300.00
340.00
380.00
420.00
460.00
500.00
540.00
580.00
620.00
660.00
700.00
TIME

FIGURE A3 - 23

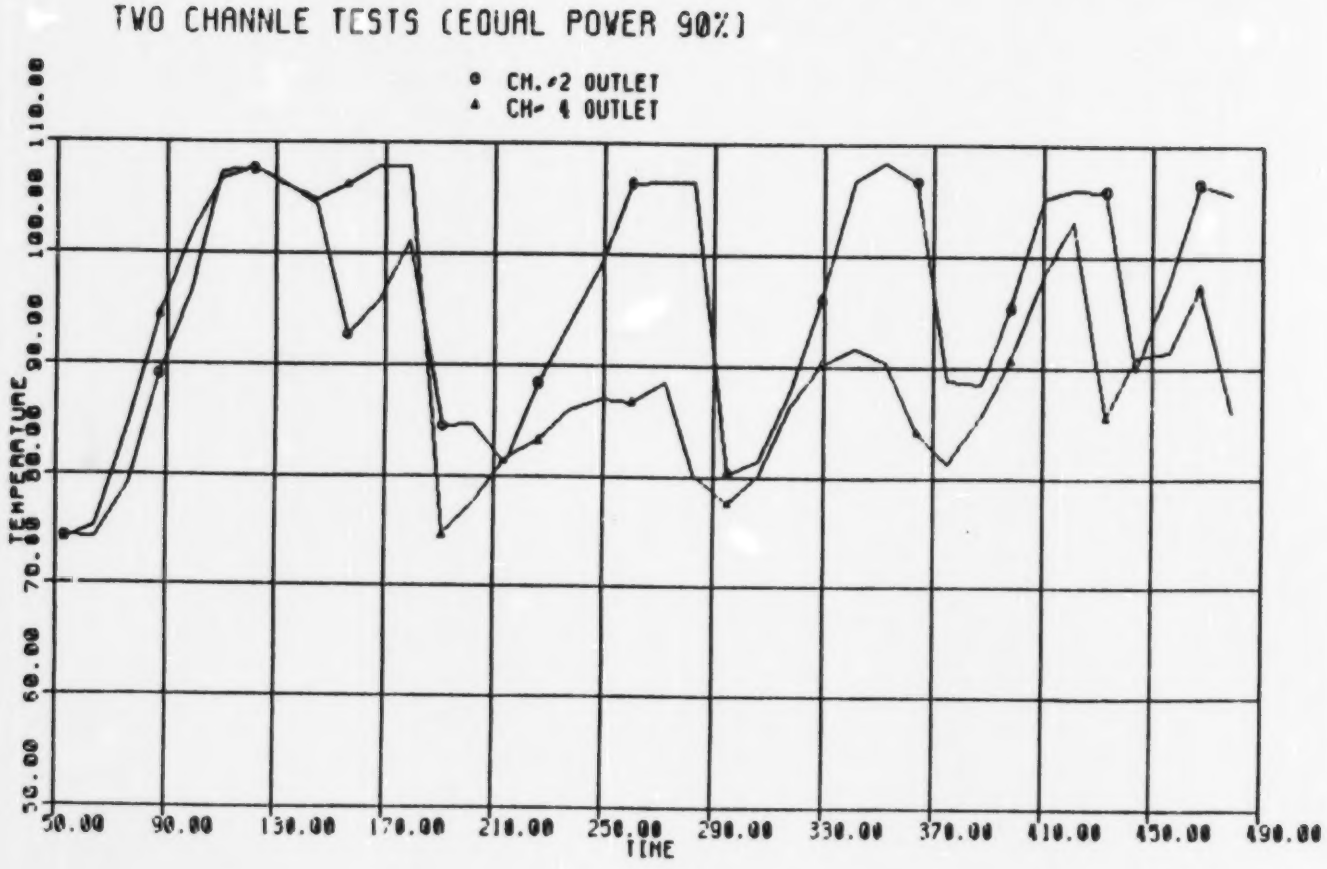

TWO CHANNLE TESTS (EQUAL POWER 90%)
CH.#2 OUTLET
CH-4 OUTLET
TEMPERATURE
50.00
60.00
70.00
80.00
90.00
100.00
110.00
50.00
90.00
130.00
170.00
210.00
250.00
290.00
330.00
370.00
410.00
450.00
490.00
TIME

FIGURE A3 - 24